

AL/OE-CR-1995-0005



**DESKTOP REPORT FOR CORROSION CONTROL TREATMENT  
THULE AIR FORCE BASE, GREENLAND**

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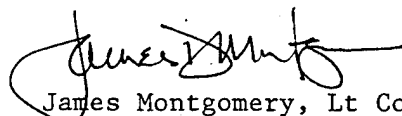
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13. ABSTRACT (Maximum 200 words) On 7 Jun 91, US EPA promulgated National Primary Drinking Water Regulations (NPDWRs) for lead and copper (referred to here as the Lead and Copper Rule [LCR]). The LCR requires public water systems (PWSs) to either demonstrate that existing lead and copper levels in consumers' tap water are below acceptable levels (the action level [AL], or that an optimal corrosion control treatment technique has been implemented to reduce lead and copper levels to below the AL. Thule AB, Greenland exceeded the action level for lead and for copper. Thule AB must submit recommendations for optimal corrosion control to Space Command. Recommended corrosion control treatment techniques will be based on a desktop evaluation. This report reviews the insallation's lead and copper sampling history, source water quality, water treatment processes, results of water quality parameter sampling, and information concerning the water distribution system. Using EPA protocols spelled out in the LCR Guidance Manuals, a desktop treatment evaluation is presented herein.				
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# **DESKTOP REPORT FOR CORROSION CONTROL TREATMENT VALIDATION THULE AB, GREENLAND**

## **TABLE OF CONTENTS**

AUTHORIZATION .....	1
SCOPE OF WORK .....	1
STEP 1 - DEFINE EXISTING CONDITIONS .....	2
STEP 2 - MONITOR SOURCE WATER .....	6
STEP 3 - DEFINE CONSTRAINTS .....	7
STEP 4 - IDENTIFY CORROSION CONTROL PRIORITIES .....	8
STEP 5 - ELIMINATE UNSUITABLE APPROACHES .....	8
STEP 6 - EVALUATE VIABLE APPROACHES .....	9
STEP 7 - RECOMMEND OPTIMAL TREATMENT .....	10
SUMMARY .....	13

## **LIST OF FIGURES**

FIGURE 1	LOGIC DIAGRAM FOR EVALUATING ALTERNATIVE CORROSION CONTROL APPROACHES .....	3
FIGURE 2	THULE AB LOCATION MAP .....	4

By _____	
Distribution/_____	
Availability Codes	
Dist	Avail and/or Special
A-1	

## LIST OF TABLES

TABLE 1	SUMMARY TABLE FOR SODIUM SILICATE CORROSION CONTROL . . . . .	12
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## APPENDICES

APPENDIX A	DESKTOP EVALUATION SHORT FORM FOR SMALL AND MEDIUM PWS TREATMENT RECOMMENDATIONS	
APPENDIX B	CHECKLIST FOR PWS DESK-TOP EVALUATIONS	
APPENDIX C	SAMPLING AND TEST RESULTS FOR COPPER AND LEAD	
APPENDIX D	CORROSION CONTROL USING SODIUM SILICATE IN YORK, MAINE	

DESKTOP REPORT  
FOR  
CORROSION CONTROL TREATMENT VALIDATION  
THULE AB, GREENLAND

AUTHORIZATION

The Department of the Air Force has authorized Pacific Environmental Services, Inc. (PES) to prepare a Desktop Report for Corrosion Control Treatment Validation at Thule AB by Delivery Order 41 to Contract F33615-89-D-4000. The report was directed by the 21st Medical Group, Bioenvironmental Engineering, Peterson AFB, Colorado.

SCOPE OF WORK

The United States Environmental Protection Agency (USEPA) was required to develop drinking water standards for contaminants which impose potential health risks under the 1986 Amendments to the Safe Drinking Water Act. The Lead and Copper Rule (LCR) was promulgated by the USEPA to set standards for lead and copper in drinking water. The United States Air Force (USAF) Space Command regulates the implementation of the rule for the Thule AB (Base) water system.

This Desktop Report is required because the Base exceeded both the copper and lead action levels on laboratory testing in July 1993 of 16 sampling sites for the LCR. There are less than 1,000 personnel assigned to the Base, which classifies the Base as a small public water supply for purposes of LCR monitoring.

The Desktop Report follows the seven steps described in the EPA 81-B-92-002, Lead and Copper Rule Guidance Manual issued by the USEPA (hereafter called the LCR Manual). These seven steps consist of:

- |        |                            |
|--------|----------------------------|
| Step 1 | Define Existing Conditions |
| Step 2 | Monitor Source Water       |
| Step 3 | Define Constraints         |

- |        |                                       |
|--------|---------------------------------------|
| Step 4 | Identify Corrosion Control Priorities |
| Step 5 | Eliminate Unsuitable Approaches       |
| Step 6 | Evaluate Viable Approaches            |
| Step 7 | Recommend Optimal Treatment           |

Each of the seven steps will be discussed in more detail in this Desktop Report. The information is summarized in the Desktop Evaluation Short Form for Small and Medium PWS Treatment Recommendations included as Appendix A of this report. The Checklist for PWS Desk-Top Evaluations, also taken from the LCR Manual, is found in Appendix B.

The LCR Manual logic diagram, shown in Figure 1 on the next page, presents the process involved in performing desk-top evaluations for selecting optimal treatment. This procedure initially eliminates any infeasible treatment approaches and then determines the water quality conditions defining optimal corrosion control treatment. Among the resulting alternatives, optimal treatment is to be selected based on the following criteria:

- the results of lead and copper tap sampling;
- corrosion control performance based on either the reductions in lead and copper solubilities or the likelihood of forming protective scales;
- the feasibility of implementing the treatment alternative on the basis of the constraints identified;
- the reliability of the alternative in terms of operational consistency and continuous corrosion control protection; and,
- the estimated costs associated with implementing the alternative treatments.

#### STEP 1 - DEFINE EXISTING CONDITIONS

##### Base

Thule Air Base is located in northwestern Greenland, approximately 950 miles south of the North Pole and 800 miles north of the Arctic Circle (Figure 2). The base is home to the 12th Space Warning Squadron (12 SWS), which provides warning of ballistic missile raids against the United States and Canada to the unified and specified commands. In addition, Detachment 3, 2nd Satellite Tracking Group,

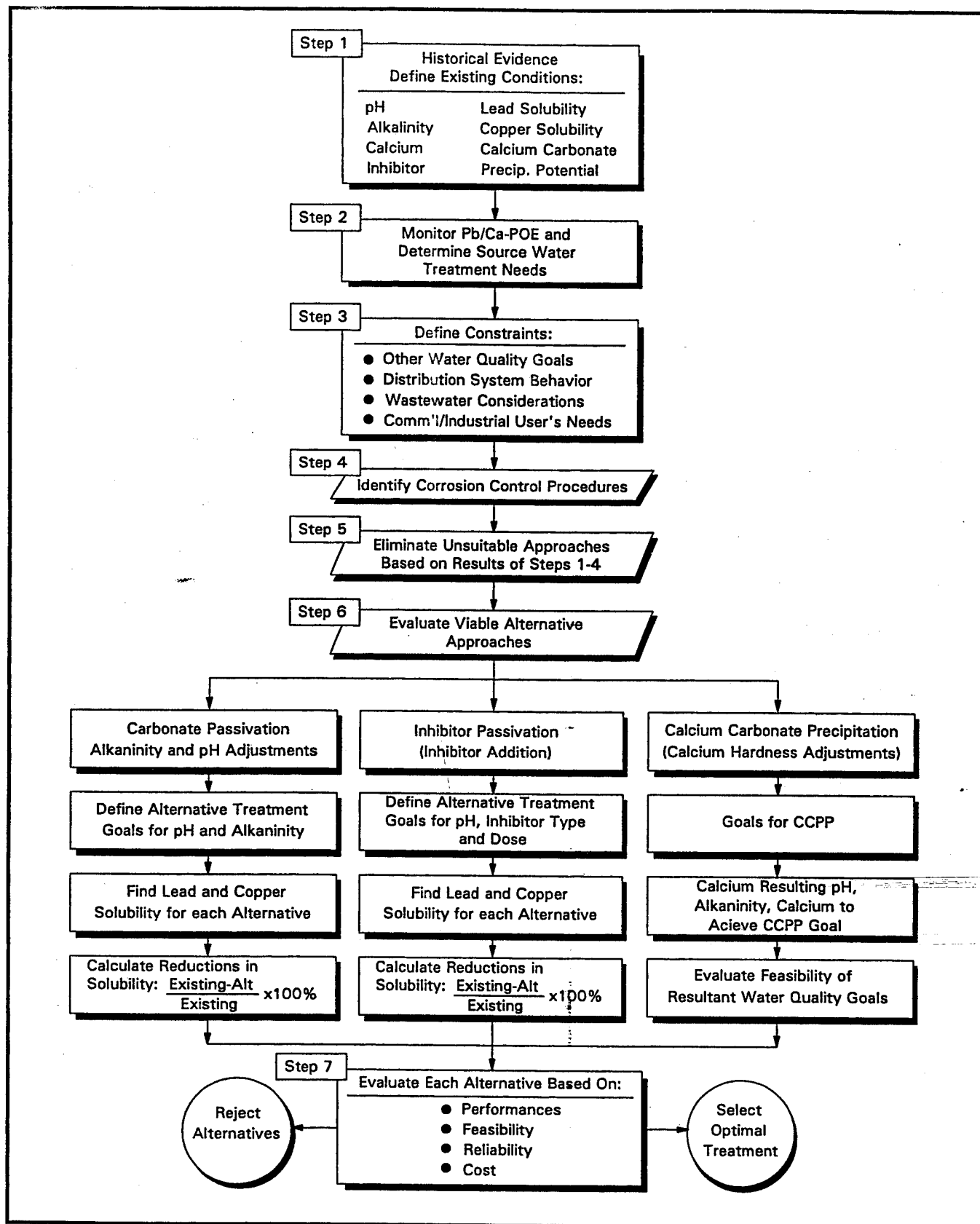


Figure 1 Logic Diagram for Evaluating Alternative Corrosion Control Approaches

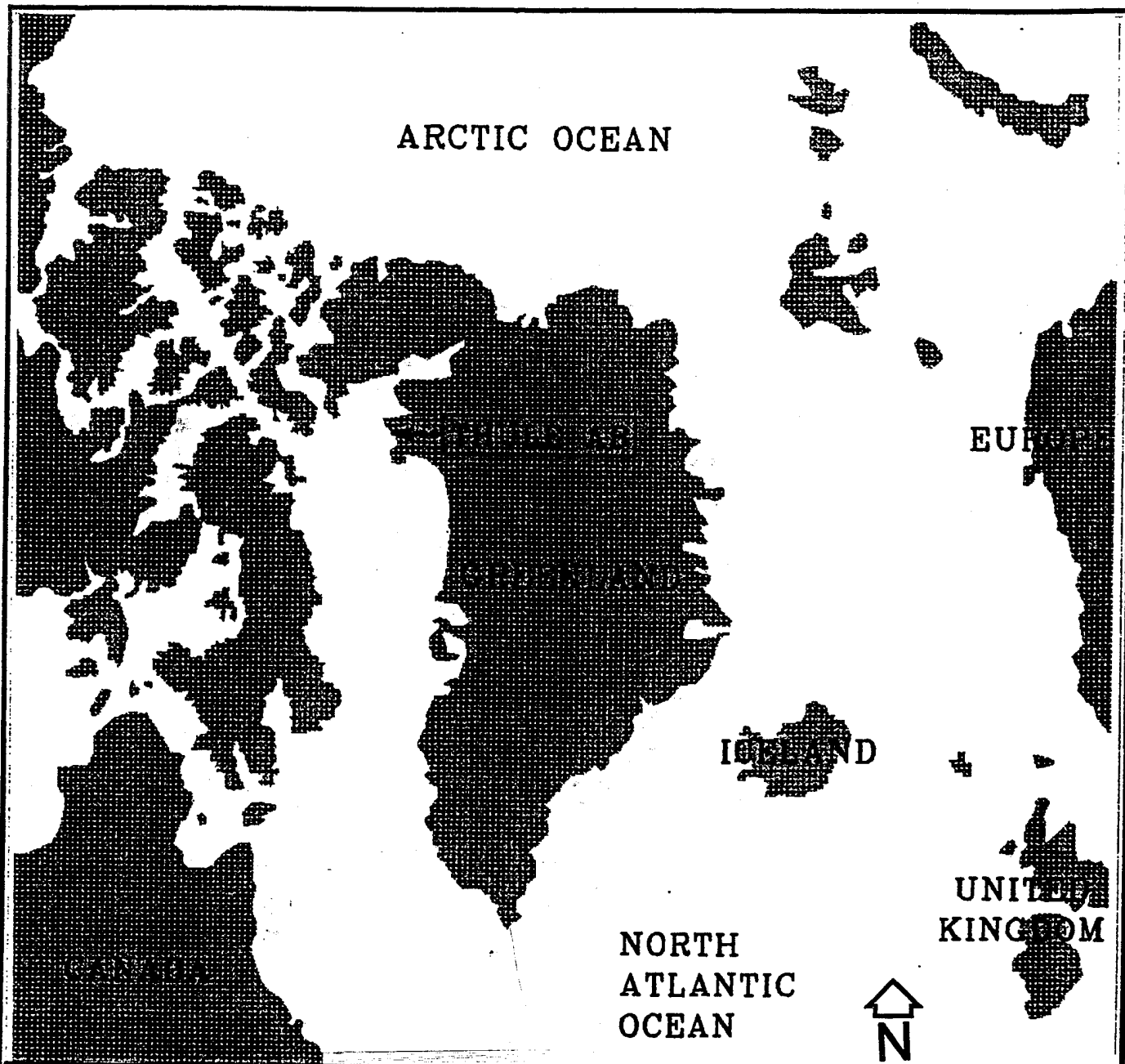


FIGURE 2 LOCATION MAP

monitors and tracks earth satellite vehicles in support of space surveillance operations. The Base is also tasked with supporting United States, allied, and international military, scientific, and logistic operations conducted in northern Greenland.

The Base obtains its water from a surface supply, Lake Crescent. The water is treated in a water filtration plant which is sited adjacent to the lake.

Water temperature at this point is about 2 °C (36 °F). Suspended matter in the water withdrawn from the lake is removed using a Hydrolit CAI sand filtration (sand and carbon-type mixture) system manufactured by SILHORKO, a Danish company. The filters use 1.5 tons of sand material, which is changed when turbidity reaches preset limits.

The filtered water is chlorinated at the water treatment plant and then pumped 10 miles to storage tanks on the main base. The storage tanks are steel with internal epoxy coatings. The water temperature is raised to between 5 and 10 ° C using heating equipment in the storage tank area.

#### Pipe Materials

Chlorinated water is piped 10 miles to the distribution storage tanks on base. The transmission piping is 8-inch diameter high density polyethylene (HDPE). Most of the exterior piping used on the Base is HDPE and varies in size from 8-inch to 2-inch. Most, if not all, of the interior piping consists of copper pipe with lead soldered joints. The copper piping was installed by the Army Corps of Engineers in 1956 and 1957. There have been minor modifications since that time. All faucets, goosenecks, elbows, and valve materials are chrome plated brass or copper (GSA catalogue materials). Brass faucets and fittings often contain significant percentages of lead which can leach out of the brass and contribute to the lead measured in the first-draw samples required for LCR testing.

The water distribution branch that goes to the J-Site (BMEWS) is constructed of new steel pipe that was recently installed. Hexameta phosphate is being added to this branch piping for a three-year period to create an inner coating.

#### LCR Testing

Initial sample collection was performed on 30 July 1993. In addition to the source water, water samples were collected from 16 sites located throughout the Base. Laboratory testing for copper and lead was performed by Armstrong Laboratory at Brooks AFB using USEPA approved test methods. The copper concentration in the 90th percentile sample was 2.0 mg/L. The lead concentration in the 90th percentile sample was 0.05 mg/l. These exceed the LCR action levels of 1.3 mg/L for copper and 0.015 mg/l for lead. Results of these tests are presented in Appendix C.

Tap water samples were collected from 22 sites plus the source water on 2 February 1994. Two of the three sites which had exceeded the copper action level in the July 1993 sampling were included in this round of sampling. Again, the 90th percentile value exceeded the lead action level of 0.015 mg/l. Copper did not exceed action levels. Analyses for lead and copper were performed by Armstrong Laboratory. The results are presented in Appendix C.

Tap water samples were collected from 20 sites in July 1994. Two of the three sites which had exceeded the copper action level in the July 1993 sampling were included in this round of sampling. Once again, the 90th percentile value exceeded the lead action level of 0.015 mg/l and copper did not exceed action levels. Analyses for lead and copper were performed by Armstrong Laboratory. The results are presented in Appendix C.

The data for copper concentrations show that the action level was not exceeded in either of the last two rounds of sampling. The highest copper concentration found in these tests was 0.64 mg/L, less than half the action level of 1.3 mg/L. It would appear, therefore, that excessive copper levels are not a continuing problem and should not be the focus of the corrective actions.

The data for lead concentrations is substantially different than for copper. The action levels for lead were exceeded in all three rounds of sampling. There is no clear pattern to the copper levels in the various buildings. The fact that high lead levels were found in a particular building during one round of sampling does not seem to be related to the value that may be found during subsequent samplings. There is a suggestion in the data that lead levels may be higher in the summer months than in colder months (summer maxima lead concentrations are about 0.07 mg/L versus 0.02 mg/L in winter).

Source water (Lake Crescent) copper and lead concentrations were below the detection limits for all sampling periods.

## STEP 2 - MONITOR SOURCE WATER

The Lake Crescent water, as determined at the point-of-entry to the Base, is a low temperature ( $\sim 2^{\circ}\text{C}$ ), low pH ( $\sim 6.8$ , temperature corrected), low alkalinity ( $\sim 20$  mg/L), and low calcium hardness water source (See Appendix A.) The Langelier Index calculated for this water source on 17 September 1993 averaged -2.0 (Appendix C). Negative values for the Langelier Index indicate the water is carbonate scale dissolving at the supply temperatures, and a protective coating of precipitate is probably non-existent in the Base distribution system.

Soft, low-mineralized waters (such as the Lake Crescent water) are typically identified as the most corrosive to galvanized iron, black iron, and copper piping.

Lead piping (and lead from soldered joints) is also susceptible to lead leaching in this type of water. Residual free chlorine concentrations exceeding 0.4 mg/l may also increase corrosion (Reference for this paragraph (except added statements in parentheses): "Lead Control Strategies", page 226, American Water Works Association, 1990).

### STEP 3 - DEFINE CONSTRAINTS

The LCR provides two conditions by which constraints may be considered in limiting the availability of alternative corrosion control treatments. These two conditions are: (1) options that adversely impact other water treatment processes and cause a violation of a National Primary Drinking Water Regulations; and (2) options that are otherwise ineffective for the water system.

The Base chlorinates the water removed from Lake Crescent and pipes it 10 miles to the Base. The National Primary Drinking Water Regulations constraints associated with pH/Alkalinity are outlined in Table 3-3a of the LCR Manual. These suggest that this method of treatment may reduce inactivation effectiveness of free chlorine if the pH/alkalinity treatment is applied before chlorination or if adequate chlorine contact time is not allowed before the pH is adjusted. Also, there may be selection and implementation impacts that would affect compliance with the Total Coliform Rule, in effect since 1991. Some water systems have experienced increases in distribution system microbiological growth after corrosion control treatment was initiated. However, in most cases no adverse impact has occurred. These considerations indicate that pH/alkalinity adjustments should not be practiced at the water treatment plant, but at some downstream point in the system before the treated water enters the distribution network.

The National Primary Drinking Water Regulations constraints associated with inhibitor treatments are outlined in Table 3-3b of the LCR Manual. These suggest that this method of treatment may result in depletion of disinfection residuals within the distribution system if there are existing corrosion byproducts. Also, if corrosion byproducts are released after the application of inhibitors, coliforms may be detected more frequently and confluent growth is more likely. Additionally, under some conditions, phosphate-based inhibitors may stimulate biofilms in the distribution system.

The following functional constraints should be considered in making a corrosion control treatment alternative selection:

- Inhibitor addition or pH/Alkalinity adjustment, if necessary, would occur at the water heating and storage area by Building 1400, the point-of-entry to the Base. This will involve a building at that location (existing buildings

may suffice), chemical delivery, daily operator attention, chemical storage, chemical feed controls and chemical feed equipment,

- sodium based chemicals must be evaluated as to their effect on the total sodium level in the drinking water,
- users with specific water quality needs, such as a hospital or a heating plant, must be advised of any changes in treatment,
- The use of inhibitors may result in complaints about red water, dirty water, color, and sediment within the distribution system,

#### STEP 4 - IDENTIFY CORROSION CONTROL PRIORITIES

As presented in previous sections of this report, lead is the priority element of concern for this corrosion control analysis. The 90th percentile of lead sampling results exceed the action level of 15 ppb, while the 90th percentile of copper sampling results were well below the action level of 1.3 mg/L in all but the initial round of sampling. Lead and copper levels were below detection limits at the Lake Crescent water source, ruling out the need for source water treatment. Therefore, the primary focus for complying with the LCR is corrosion control to reduce the leaching of lead from joints and fittings in the building interior piping.

Corrosion control treatment alternatives must inhibit the dissolution of lead without substantially increasing the dissolution of copper. None of the passivation techniques to be further considered in this Desktop Report are expected to have an adverse effect on copper dissolution.

#### STEP 5 - ELIMINATE UNSUITABLE APPROACHES

##### Precipitation of Calcium Carbonate

Since the source water is low in alkalinity, calcium, and pH, adjusting the pH alone to cause deposition of calcium carbonate throughout the Base water distribution system is not practical. Likewise, adding calcium to the source water to allow precipitation of calcium carbonate does not appear to have any merit since this would increase the need for local water softeners and may decrease the life expectancy for water heaters not supplied with softened water.

## STEP 6 - EVALUATE VIABLE APPROACHES

### Phosphate Inhibitors

Phosphate inhibitors function best in the pH range 7.4 to 7.8. Because the source water pH is below 7.4 (typical pH is 6.6 - temperature adjusted) and because addition of the acidic phosphate solutions would further lower the pH, the source water pH would have to be adjusted if this inhibitor were to be used. As stated in Step 3, raising the pH should not be practiced at the water treatment plant or negative impacts on disinfection effectiveness may occur. Because the source water is low in calcium and magnesium, little of the inhibitor would be lost to competing depletion mechanisms. However, the effectiveness of these type inhibitors is difficult to predict. The Base does have experience with phosphate-based inhibitors for corrosion protection of iron piping in the distribution system.

Also, as stated in Step 3, addition of inhibitors may have negative impacts on disinfection effectiveness and water acceptability due to poor color and/or turbidity. Furthermore, because the source water is poorly buffered, maintaining the proper pH throughout the distribution system may be difficult. As noted above, if the pH varies outside the range 7.4 to 7.8, inhibitor effectiveness diminishes rapidly.

### Silicate Inhibitors

Silicate inhibitors are effective over a much broader pH range than phosphate inhibitors. This is a distinct advantage because pH throughout the distribution system may vary due to natural variations in the water temperature. Furthermore, as discussed below, controlling the pH using chemical additives would be difficult. Like the phosphate-base inhibitors, little of the silicate inhibitor would be lost to competing depletion mechanisms.

The effectiveness of silicate inhibitors is difficult to predict. Corrosion control appears to be a combination of adsorption and formation of less soluble metal-silicate compounds by combining with free metal released at the anode site of corrosion. A slightly corroded surface may be necessary to form the protective silicate film. The addition of silicate inhibitors to systems with extensive corrosion byproduct buildup may result in their release, causing red and turbid water problems.

### Alkalinity and/or pH Adjustment

Figure 3-2 of the LCR Manual shows that minimum lead solubility occurs at a pH of about 9.8 and an alkalinity of 20 to 50 mg/L. Similar conditions provide minimum copper solubility. The source water is already low in alkalinity (~20mg/L) but has a low pH ( $\leq 7$ ). If the pH were raised without any significant increase in alkalinity, theoretical lead and copper concentrations would decrease in direct relation

to the increase in pH. Theoretical lead concentrations would decrease even further if the alkalinity were raised into the 30 to 50 mg/L range. The Langlier Index is near zero at a pH of 9.8 and alkalinity of 20 mg/l. The calcium carbonate precipitation potential is still quite negative at these conditions, indicating that calcium carbonate precipitation would not occur in the water distribution lines.

These considerations indicate that caustic soda (NaOH) would be the preferred chemical for pH adjustment. Caustic soda would convert any dissolved carbon dioxide to alkalinity; thus, some increase in alkalinity can be expected. Sodium bicarbonate and sodium carbonate would also increase the alkalinity with only little to moderate increase in the pH.

Because the Lake water is poorly buffered, pH control would be expected to be quite sensitive to the added caustic. Caustic would have to be added with good agitation and the addition be controlled with a pH (temperature adjusted) feedback loop. Even then, it is likely that pH would vary throughout the distribution system due to natural variations in the water temperature and chemical reactions with the pipe materials. Note that temperature variations and chemical reactions are most likely to occur in the indoor piping systems. This is the probable location where most of the corrosion is occurring.

## STEP 7 - RECOMMEND OPTIMAL TREATMENT

Clearly, the choice of corrosion control method is either pH adjustment or silicate based inhibitor. The potential for poor pH control in critical parts of the distribution system and the effectiveness of silicate inhibitors over a wide pH range indicate that silicate inhibitors are the best alternative for reducing lead levels.

Silicate inhibitors are manufactured by fusing silica sands with a sodium or potassium salt. Sodium silicates are generally more common with sodium carbonate as the bonding salt. The sodium content of the water will increase slightly with sodium silicate addition. These generally have a silica to sodium carbonate molar ratio between 1.5 and 4. The most common form of silicate in water treatment is the 3.22 weight ratio sodium silicates at 41 'Baume' solution with 37 to 38 percent solids (Type N)<sup>1</sup>. Because the supply water typically has a low pH (temperature corrected), a more alkaline product should be considered to reduce acidity and increase the buffering capacity of the water. One such product is the 2.0 weight ratio  $\text{SiO}_2/\text{Na}_2\text{O}$  with 50.5 'Baume' solution (Type D)<sup>1</sup>. These products are in water solution, making handling and feeding convenient as well as amenable to automatic control and preclude the need for extensive tankage and equipment.

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<sup>1</sup>Registered trademarks of The PQ Corporation, Philadelphia, PA.

According to The PQ Corporation, relatively high dosages of silicate are required during the first 30 to 60 days of treatment, in order to form the initial protective coating. This initial silicate dosage is referred to as a passivation dosage, and should be 24 mg/L above the background silica level.

The actual amount of time required to establish the initial coating will depend on the amount of silicate injected, water quality, water flow rates, and system length.

After the first 30 to 60 days of treatment, or once film formation has been verified, the dosage can be reduced to a maintenance dose. It is advisable to reduce the silica dose incrementally and perform silica balances over the system as the dosage is decreased, in order to verify the protective film remains intact. See Table 1 for a summary of sodium silicate usage for corrosion control.

Assuming that the daily water usage at Thule AB averages 100,000 gallons per day, 2 gallons of the 2.0 weight ratio product (Type D) will be needed each day to maintain a silica concentration of about 8 mg/L<sup>2</sup>. On an annual basis, 14-55 gallon drums of the inhibitor are required at the maintenance dosage of 8 mg/L. The annual cost for the sodium silicate is estimated to be \$7,700 at a \$10/gallon delivered price to the port of New York.

Two metering pumps, one on-line and one standby, piping and valves, and instrumentation would also be necessary to automate feeding of the inhibitor into the distribution system near Building 1400. Safety equipment is necessary to handle the chemical and an eyewash shower must be next to the chemical area.

The feed pumps should be located in a heated structure with water, sewer, and electrical service that is situated close to the storage tanks by Building 1400. Water temperature must be at least 40°F and preferably 50°F for effective chemical feed. Jar testing is necessary to establish the pH profile for the sodium silicate.

Addition of silicate inhibitor at the water plant next to Lake Crescent is not recommended as this may negatively impact disinfection effectiveness. The chemical feed equipment, piping and valves, instrumentation, mixing tank, safety equipment, and related items is estimated to cost approximately \$30,000 for materials (stateside costs). This does not include the cost of a building if adequate space is not available in an existing facility close to Building 1400.

An EPA seminar publication, "Control of Lead and Copper in Drinking Water" (EPA/625/R-93/001) May 1993, provides information on the use of sodium silicate to control corrosion in a low alkalinity water in York, Maine. The methodology of usage, the findings from full scale application, and recommendations for usage are noted in the article (Appendix D).

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<sup>2</sup>2.25 gallons of Type D SiO<sub>2</sub> will maintain a 1mg/L dosage in 1MG of water.

TABLE 1

SUMMARY TABLE FOR SODIUM SILICATE CORROSION CONTROL<sup>3</sup>

1. Silicates are approved as direct additives to potable water. They are nonhazardous, nontoxic, and nonflammable. They do not impart any taste or odor to water.
2. American Water Works Association Standard for Liquid Sodium Silicate (ANSI/AWWA B404) reviews the use of sodium silicate in water treatment.
3. The U.S. Environmental Protection Agency recognized that silicates may be effective in controlling lead and copper corrosion in potable water systems.
4. At the dilutions typical in water treatment, most of the added silica is in the monomeric form.
5. The silica in sodium silicate solutions carries a negative charge and will migrate to anodic areas, where it can react with metallic ions and form a protective film, which will inhibit corrosion.
6. The sodium oxide present in silicate will typically raise pH. Increases in pH generally lead to decreased corrosion rates.
7. The film does not build on itself and will not obstruct water flow.
8. In areas of low water flow the supply of silica may eventually be exhausted within the effective range of the electrical forces around the anode. A sufficient water flow is required to supply additional silica.
9. In areas of low flow, the pH contribution of the silicate may also be reduced.
10. If only part of the area is protected, the remainder takes all the attack of the corrosive medium. Therefore it is important to use enough inhibitor.
11. The efficacy of the silicate treatment may vary with the type of metal.
12. The treatment has checked corrosion in systems where two dissimilar metals are in contact.
13. A passivation dose of 24 mg SiO<sub>2</sub>/L is recommended during the first 30-60 days of treatment, in order to quickly establish the protective film.
14. After the protective film has been formed, it can be maintained by feeding less silicate. The optimum silicate dosage will depend on specific water chemistry and system characteristics. In most waters a maintenance dosage of 8 mg SiO<sub>2</sub>/L is effective.

<sup>3</sup>Based on information from The PQ Corporation.

## SUMMARY

This Desktop Report followed the seven steps described in the LCR Manual. Based on water quality at the point-of-entry, existing conditions in the Base distribution system, constraints and other conditions which eliminated unsuitable approaches, and an evaluation of the remaining viable alternatives, an optimal corrosion control treatment was recommended. Addition of a silica based inhibitor is the recommended method.

The chemicals, chemical handling equipment, and safety equipment must be housed in a heated structure supplied with utilities. This structure should be located close to Building 1400 where the potable water enters the Base distribution system.

The selected corrosion control treatment should perform satisfactorily, provide consistent and continuous protection, and be easily implemented.

## **APPENDIX A**

## Desktop Evaluation Short Form for Small and Medium PWS Treatment Recommendations

### A. PWS General Information:

1. PWS Identification No.	_____
2. Contact Person:	_____
Name	_____
Mailing Address	_____
	_____
Telephone	_____ Fax _____
3. Population served	_____
4. Person responsible for preparing this form:	_____
Name	_____
Signature	_____
Telephone	_____

### B. PWS Technical Information:

1. Monitoring Results:						
Sampling dates: From _____		To _____				
First Flush Tap Monitoring Results:						
Lead:						
Minimum Concentration	=	_____	mg/L			
Maximum Concentration	=	_____	mg/L			
90th percentile	=	_____	mg/L			
Copper:						
Minimum Concentration	=	_____	mg/L			
Maximum Concentration	=	_____	mg/L			
90th percentile	=	_____	mg/L			
Point-of-Entry Tap Monitoring Results:						
		Points of Entry				
		1	2	3	4	5
Lead Concentration in mg/L:	<0.1	_____	_____	_____	_____	_____
Copper Concentration in mg/L:	<0.001	_____	_____	_____	_____	_____
pH:	6.6	_____	_____	_____	_____	_____
Temperature, °C:	2	_____	_____	_____	_____	_____
Alkalinity, mg/L as CaCO <sub>3</sub> :	20	_____	_____	_____	_____	_____
Calcium, mg/L as Ca:	6.4	_____	_____	_____	_____	_____
Conductivity, µmho/cm@25°C:	90	_____	_____	_____	_____	_____
Phosphate, mg/L as P:	_____	_____	_____	_____	_____	_____
Silicate, mg/L as SiO <sub>2</sub> :	_____	_____	_____	_____	_____	_____

**1. Monitoring Results (continued):****Water Quality Parameter Distribution System Monitoring Results:**

Indicate whether field or laboratory measurement.

		Field	Lab
pH: minimum	= _____ maximum = _____	_____	_____
alkalinity:		_____	_____
minimum	= _____ mg/L as CaCO <sub>3</sub>		
maximum	= _____ mg/L as CaCO <sub>3</sub>		
temperature:			
minimum	= _____ °C	_____	_____
maximum	= _____ °C		
calcium:			
minimum	= _____ mg/L as Ca	_____	_____
maximum	= _____ mg/L as Ca		
conductivity:			
minimum	= _____ μmho/cm @ 25°C	_____	_____
maximum	= _____ μmho/cm @ 25°C		
orthophosphate:			
(if phosphate-based inhibitor is used)			
minimum	= _____ mg/L as P		
maximum	= _____ mg/L as P		
silica:			
(if silica-based inhibitor is used)			
minimum	= _____ mg/L as SiO <sub>2</sub>		
maximum	= _____ mg/L as SiO <sub>2</sub>		

**2. Existing Conditions:**Is treatment used? yes \_\_\_\_\_ no x \_\_\_\_\_

Identify water source(s):

Source No. 1 Lake Crescent

Source No. 2 \_\_\_\_\_

Source No. 3 \_\_\_\_\_

If treatment is used, is more than one source used at a time?

yes \_\_\_\_\_ no \_\_\_\_\_

Identify treatment processes used for each source:

Process	No. 1	No. 2	No. 3
Presedimentation	<u>No</u> _____	_____	_____
Aeration	<u>No</u> _____	_____	_____
Chemical mixing	<u>No</u> _____	_____	_____
Flocculation	<u>No</u> _____	_____	_____
Sedimentation	<u>No</u> _____	_____	_____
Recarbonation	<u>No</u> _____	_____	_____

**2. Existing Conditions (continued):**

Identify treatment processes used for each source:

Process	No. 1	No. 2	No. 3
2nd Stage mixing	_____	_____	_____
2nd Stage flocculation	_____	_____	_____
2nd Stage sedimentation	_____	_____	_____
Filtration:			
Single medium	_____	_____	_____
Dual media	_____	_____	_____
Multi-media	<u>Yes</u>	_____	_____
GAC cap on filters	<u>Yes</u>	_____	_____
Disinfection:			
Chlorine	<u>Yes</u>	_____	_____
Chlorine dioxide	_____	_____	_____
Chloramines	_____	_____	_____
Ozone	<u>No</u>	_____	_____
Granular Activated Carbon	_____	_____	_____

List chemicals normally fed:

List chemicals sometimes fed:

**3. Present Corrosion Control Treatment:**None X - Phosphate used in Segment J (iron pipe)

Inhibitor \_\_\_\_\_

Date initiated \_\_\_\_\_

Present dose \_\_\_\_\_

Range in Residual in Distribution System:

Maximum \_\_\_\_\_ mg/L Minimum \_\_\_\_\_ mg/L

Brand name \_\_\_\_\_

Type \_\_\_\_\_

Has it been effective? Please comment on your experience.

pH/alkalinity adjustment \_\_\_\_\_

pH Target \_\_\_\_\_

Alkalinity Target \_\_\_\_\_ mg/L CaCO<sub>3</sub>

Calcium adjustment \_\_\_\_\_

Calcium Target \_\_\_\_\_ mg/L CaCO<sub>3</sub>

**4. Water Quality**

Complete the table below for typical untreated and treated water quality data. Copy this form as necessary for additional sources. Include data for each raw water source, if surface supplies are used, and finished water quality information (point of entry) from each treatment plant. If wells are used, water quality information from each well is acceptable but not necessary if several wells have similar data. For groundwater supplies, include a water quality summary from each wellfield or grouping of wells with similar quality.

Include available data for the following:

Parameter	Untreated Supply	Treated Water (point of entry)
pH, units	6.6	
Alkalinity, mg/L as CaCO <sub>3</sub>	20	
Conductivity, $\mu$ mho/cm @ 25°C	90	
Total dissolved solids, mg/L		
Calcium, mg/L Ca	6.4	
Hardness, mg/L as CaCO <sub>3</sub>	35	
Temperature, °C	2 degrees C	
Chloride, mg/L		
Sulfate, mg/L		

**5. Distribution System:**

Does the distribution system contain lead service lines?

Yes \_\_\_\_\_ No X \_\_\_\_\_

If your system has lead service lines, mark below the approximate number of lines which can be located from existing records.

None \_\_\_\_\_ Some \_\_\_\_\_ Most \_\_\_\_\_ All \_\_\_\_\_

Is the distribution system flushed?

None X \_\_\_\_\_ Some \_\_\_\_\_ Most \_\_\_\_\_ All \_\_\_\_\_

**6. Historical Information**

Is there a history of water quality complaints?

yes\_\_\_\_ no X

If yes, then answer the following:

Are the complaints documented? yes\_\_\_\_ no\_\_\_\_

Mark the general category of complaints below. Use:

- 1 for some complaints in this category
- 2 for several complaints in this category
- 3 for severe complaints in this category

Categories of complaints:

Taste and odor \_\_\_\_\_  
Color \_\_\_\_\_  
Sediment \_\_\_\_\_  
Other (specify) \_\_\_\_\_

Have there been any corrosion control studies?

yes\_\_\_\_ no X

If yes, please indicate:

Date(s) of study From \_\_\_\_\_ To \_\_\_\_\_

Study conducted by PWS personnel? yes\_\_\_\_ no\_\_\_\_

Brief results of study were:

(Optional) Study results attached yes\_\_\_\_ no\_\_\_\_

Were treatment changes recommended? yes\_\_\_\_ no\_\_\_\_

If yes:

Were treatment changes implemented? yes\_\_\_\_ no\_\_\_\_

Have corrosion characteristics of the treated water changed? yes\_\_\_\_ no\_\_\_\_

If yes, how has change been measured?

General observation \_\_\_\_\_  
Coupons \_\_\_\_\_  
Frequency of complaints \_\_\_\_\_  
Other \_\_\_\_\_

Briefly indicate, if other:

**7. Treatment Constraints:**

Optimal corrosion control treatment means the corrosion control treatment that minimizes the lead and copper concentrations at users' taps while insuring that the treatment does not cause the water system to violate any national primary drinking water regulations. Please indicate below which constraints to treatment will apply to your PWS. Use the following code:

- 1 Some constraint = Potential Impact but Extent is Uncertain
- 2 Significant constraint = Other Treatment Modifications Required to Operate Option
- 3 Severe constraint = Additional Capital Improvements Required to Operate Option
- 4 Very severe constraint = Renders Option Infeasible

Constraint	Treatments			
	pH/Alkalinity Adjustment	Calcium Adjustment	Inhibitor	
			PO <sub>4</sub>	Si
<b>A. Regulatory</b>				
SOCs/IOCs				
SWTR: Turbidity				
Total Coliforms	1		1	
SWTR/GWDR: Disinfection	1		1	
Disinfection Byproducts				
Lead and Copper Rule				
Radionuclides				
<b>B. Functional</b>				
Taste & Odor				
Wastewater Permit				
Aesthetics			1	1
Operational		4		
Other				

**8. Desktop Evaluation**

Briefly summarize the review of the corrosion control literature that pertains to your PWS. A report or summary can be appended to this form if preferred.

LCR Guidance Manual,

- EPA Seminar Publication; "Control of Lead and Copper in Drinking Water"
- Information from The PQ Corporation

Were other similar facilities located which are experiencing successful corrosion control?

yes X no       

If yes, identify their corrosion control treatment method.

None             
pH/Alkalinity adjustment             
Calcium adjustment             
Inhibitor             
Phosphate based             
Silica based   X  

**9. Recommendations**

The corrosion control treatment method being proposed is:

pH/Alkalinity adjustment             
Target pH is        units  
Target alkalinity is        mg/L as CaCO<sub>3</sub>  
Calcium adjustment             
Target calcium concentration is        mg/L Ca  
Inhibitor             
Phosphate based             
Brand Name                                   
Target Dose        mg/L  
Target residual        mg/L orthophosphate as p  
Silica based   X    
Brand Name Type D Sodium Silicate  
Target Dose   8   mg/L  
Target residual        mg/L as SiO<sub>2</sub>

Rationale for the proposed corrosion control treatment is:

Discussed in the enclosed report   X    
Briefly explained below

List your proposed operating guidelines:

<u>Parameter</u>	<u>Operating Range</u>
pH	8.0 (Temperature Corrected to 25° C)
SiO <sub>2</sub> (passivation)	24 mg/L
SiO <sub>2</sub> (maintenance)	8 mg/L

Briefly explain why these guidelines were selected.

Recommended by chemical producer

10. Please provide any additional comments that will assist in determining optimal corrosion control treatment for your PWS.

## **APPENDIX B**

## SCREENING OF ALTERNATIVES

**Table 3-6. Checklist for PWS Desk-Top Evaluations**

**I. Historical Evidence Review:**

Did your utility:

**YES**

**NO**

- a. Determine Initial Water Quality
  - WQP-POE and WQP-DIS
  - Pb/Cu-POE
  - Lead Solubility
  - Copper Solubility
  - CCPP Index Value

X	
X	
X	
X	
X	
	X

- b. Conduct Prior Corrosion Control Investigations

	X
--	---

- c. Assess Corrosion Activity in the Distribution System for:
  - Lead and Copper
  - Iron
  - A/C Pipe
  - Other Materials, please specify

	X
	X
	X
	X

- d. Review the Literature

X	
---	--

- e. Identify Comparable PWS Experience with Corrosion Control Treatment

X	
---	--

(If YES, what was the overall performance of the alternative treatment approaches)

	Very Good	Good	Poor	Adverse
pH/Alkalinity Adjustment				
Calcium Adjustment				
Corrosion Inhibitors				
Phosphates				
Silicates		X		

- f. Source Water Treatment Status

Required  
Recommended  
Optional  
Not Necessary

X

# SCREENING OF ALTERNATIVES

**Table 3-6. Checklist for PWS Desk-Top Evaluations (continued)**

- g. Based on your water quality characteristics, check the suggested treatment approach(es) per Figure 3-7 in Volume II of the Guidance Manual.

pH/Alkalinity Adjustment

Calcium Adjustment

Corrosion Inhibitors

Phosphates

Silicates

X
X
X

## II. Constraint Definitions

Is the constraint identified applicable to your system?  
(Based on Rankings of 3 or 4 on Form 141-C)

### Regulatory Constraints:

SOCs/IOCs

SWTR: Turbidity

Total Coliforms

SWTR/GWTR: Disinfection

D/DBPs

LCR

Radionuclides

- YES

NO

	X
	X
X	
X	
X	
	X
	X

### Functional Constraints:

Taste and Odor

Wastewater Permit

Aesthetics

Operational

Other

	X
	X
X	
	X
	X

## III. Were any treatment approaches eliminated from further consideration in the desk-top evaluation?

pH/Alkalinity Adjustment

Calcium Adjustment

Corrosion Inhibitors:

Phosphates

Zinc Orthophosphate

Sodium Orthophosphate

\_\_\_\_\_ Orthophosphate

Poly-ortho-phosphates

Polyphosphates

Silicates

YES

NO

	X
X	
	X
	X
	X

## SCREENING OF ALTERNATIVES

**Table 3-6. Checklist for PWS Desk-Top Evaluations (continued)**

IV. For each of the feasible treatment alternatives, did your system evaluate the following in the desk-top evaluation?

Performance  
Feasibility  
Reliability  
Costs

YES	NO
<input checked="" type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>
<input checked="" type="checkbox"/>	<input type="checkbox"/>

V. What is the recommended treatment approach?

Source Water Treatment:  
Method, specify:

YES	NO
<input type="checkbox"/>	<input checked="" type="checkbox"/>

Corrosion Control Treatment

<input checked="" type="checkbox"/>	<input type="checkbox"/>
-------------------------------------	--------------------------

pH/Alkalinity Adjustment

Calcium Adjustment

Corrosion Inhibitors:

Phosphates

Specify type:

<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>
<input type="checkbox"/>	<input type="checkbox"/>
<input type="checkbox"/>	<input checked="" type="checkbox"/>

Silicates

Specify type:

<input checked="" type="checkbox"/>	<input type="checkbox"/>
-------------------------------------	--------------------------

## **APPENDIX C**

Sheet1

		Thule AFB Lead and Copper Results					
		July	93	Feb	94	July	94
	<u>Bldg No</u>	<u>Cu</u>	<u>Pb</u>	<u>Cu</u>	<u>Pb</u>	<u>Cu</u>	<u>Pb</u>
	Lake	0.1	0.001	0.02	0.001		
	1400	0.2	0.01	0.02	0.018	0.02	0.01
	97	1.5	0.003	0.08	0.011	0.12	0.055
	105	2.1	0.067				
	107	0.1	0.001	0.02	0.001	0.02	0.001
	115	0.8	0.003	0.05	0.001	0.08	0.003
	126	0.8	0.051				
	127	1.5	0.001	0.28	0.001	0.2	0.001
	245			0.25	0.018	0.23	0.02
	256			0.12	0.001	0.062	0.001
	325			0.08	0.001	0.064	0.001
	334	0.2	0.004				
	362	0.7	0.006				
	367	0.9	0.072				
	426			0.27	0.001		
	463			0.15	0.018	0.133	0.022
	580			0.04	0.002	0.062	0.028
	608	0.2	0.006	0.03	0.001	0.03	0.002
	619			0.02	0.001	0.02	0.001
	630			0.05	0.011	0.039	0.002
	707	0.6	0.021	0.06	0.007	0.032	0.002
	708	0.4	0.007	0.02	0.003	0.058	0.016
	750	0.9	0.018	0.03	0.002	0.02	0.011
	760	0.2	0.016	0.09	0.018	0.064	0.012
	774			0.64	0.018		
	801			0.22	0.022	0.158	0.007
	836			0.04	0.003	0.148	0.012
	837	0.1	0.001				
	935			0.02	0.001	0.014	0.065

DEPARTMENT OF THE AIR FORCE  
12th Space Warning Squadron  
APO, AE 09704-5000

26 May 94

MEMORANDUM FOR Pacific Environmental Services (PES)

FROM: 12 SWS/SGB  
750 Hospital Loop  
Unit # 82501  
APO AE 09704-5000

SUBJ: Potable Water Characteristics and Distribution System Materials of Construction Information

1. The subject information, as discussed with Bob Forbes on 6 April 1994, is provided for the Thule AB drinking water study.
  - a. Pipe materials used base wide: Exterior - Most pipe is high density polyethylene, the rest is standard steel. Interior - most if not all consists of copper pipe and lead solder.
  - b. Copper Piping Installation Date: 1956 through 1957, by the Army Corps of Engineers. There have been minor ongoing modifications since this time
  - c. Faucet, Gooseneck, Elbow, and Valve Materials: All of these are chrome plated brass or copper (GSA catalog materials)
  - d. Storage Tank Materials: Steel with an internal epoxy coating.
  - e. Filtration System: Sand Filtration (sand and carbon-type mixture) used on a filtration system referred to as a Hydrolit CAI. The system is manufactured and replenished by a Danish company named "SILHORKO". The filters utilize 50 bags (1.5 tons) of sand material and is changed according to the turbidity readings.
  - f. Water Treatment Used: Chlorination for the entire system. For the branch that goes to J-Site (BMEWS), Hexameta Phosphate is added in addition to chlorine. The phosphate is added because the steel pipe is new and is being treated to create an inner coating for a three year period.
2. Enclosed please find the Blueprints for the water supply system here at Thule. If you require additional information or need clarification please contact me, TSgt Soriano, at DSN 268-1211, ext 2782 Fax: 3460, or commercial telephone number 01129950636.



MANUEL J. SORIANO, TSgt, USAF  
Bioenvironmental Engineering Services  
Quality Assurance Evaluator

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

ALC 18  
CHARACTERISTICS  
SAMPLING

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930084

Source: LAKE CRESCENT  
Supply

SAMPLE TYPE: POTABLE WATER

SITE IDENTIFIER: PS001

DATE RECEIVED: 931126

DATE COLLECTED: 931117

DATE REPORTED: 931206

SAMPLE SUBMITTED BY: 12 FWS/SGB

PRESERVATION GROUP G

OEHD SAMPLE #: 93058131 ANALYSIS DATE: 931203

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Alkalinity (total)	20	mg/L	EPA 310.2
Langelier Index	-3.25		STD METH 203
Residue, filterable	66	mg/L	EPA 160.1


pH 6.5  
Temp 2°C

1. NO for Record

7 JAN 93

These are results of drinking water characteristics due to Thule AFB Exceeding standards for the copper and lead rule. Peterson AFB Bioenvironmental Engineering section has been given a copy of this report. Waiting word on firming up funds to pay for the water study contractors (PES, PACIFIC ENVIRONMENTAL SERVICES) from Col. Martin at 21 MG/SGPB, PAFB, CO.

Reviewed by:

TSgt SORIANO  


YOLANDA SALMON

Daryl S. Bird, GS-12  
Chief, Inorganic Analysis Function

TO:

12 FWS/SGB

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

file 18

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930085      OEHL SAMPLE NO: 93058132  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: PS001      DATE RECEIVED: 931126  
DATE COLLECTED: 931117      DATE REPORTED: 940118  
DATE ANALYZED: 931214  
SAMPLE SUBMITTED BY: 12 FWS/SGB

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Calcium	6.4	mg/L	EPA 200.7
Magnesium	5.0	mg/L	EPA 200.7
Hardness	37	mg/L	EPA 200.7

pH 6.6  
Temp 2°C

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SGB

PAGE 1

APO AE 09704-5000

AL/DEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

SUMMER

Cu & Pb

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930041

OEHL SAMPLE NO: 93039755

SAMPLE TYPE: POTABLE WATER

SITE IDENTIFIER: XX097

DATE RECEIVED: 930809

DATE COLLECTED: 930730

DATE REPORTED: 930910

DATE ANALYZED: 930831

SAMPLE SUBMITTED BY: 12 FWS/SGB

BDG 97

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	1.5	mg/L	EPA 200.7
Lead	0.003	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

12 FWS/SGB

PAGE 1

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BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930042                      OEHL SAMPLE NO: 93039756  
SAMPLE TYPE:            POTABLE WATER  
SITE IDENTIFIER: XX105                      DATE RECEIVED: 930809  
DATE COLLECTED: 930730                      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BIDG 105

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	2.1	mg/L	EPA 200.7
Lead	0.067	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

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PAGE 1

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REPORT OF ANALYSIS

BASE SAMPLE NO: GP930043      OEHL SAMPLE NO: 93039257  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX107      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BLDG 107

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	<0.1	mg/L	EPA 200.7
Lead	0.001	mg/L	EPA 239.2

Comments:

< - Signifies none detected and the detection limits.

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

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PAGE 1

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2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930044      OEHL SAMPLE NO: 93039758  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX115      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BLDG 115

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.8	mg/L	EPA 200.7
Lead	0.003	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

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PAGE 1

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BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930046                      OEHL SAMPLE NO: 93039760  
SAMPLE TYPE:            POTABLE WATER  
SITE IDENTIFIER: XX236                      DATE RECEIVED: 930809  
DATE COLLECTED: 930730                      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

Bldg 126

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.8	mg/L	EPA 200.7
Lead	0.051	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

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PAGE 1

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2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930045                      OEHL SAMPLE NO: 93039759  
SAMPLE TYPE:            POTABLE WATER  
SITE IDENTIFIER: XX127                      DATE RECEIVED: 930809  
DATE COLLECTED: 930730                      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

Bldg 127

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	1.5	mg/L	EPA 200.7
Lead	0.001	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

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PAGE 1

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2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930047      OEHL SAMPLE NO: 93039761  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX334      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BUDG 334

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.2	mg/L	EPA 200.7
Lead	0.004	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

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APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930048      OEHL SAMPLE NO: 93039762  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX362      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BIDG 362

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.7	mg/L	EPA 200.7
Lead	0.006	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

12 FWS/SGB

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930049      OEHL SAMPLE NO: 93039763  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX367      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BLDG 367

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.9	mg/L	EPA 200.7
Lead	0.072	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

12 FWS/SGB

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930050      OEHL SAMPLE NO: 93039764  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX608      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BUDG 608

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.2	mg/L	EPA 200.7
Lead	0.006	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

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12 FWS/SGB

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930051      OEHL SAMPLE NO: 93039765  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX707      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BLDG 707

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.6	mg/L	EPA 200.7
Lead	0.021	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

12 FWS/SGB

APO AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930052                      OEHL SAMPLE NO: 93039766  
SAMPLE TYPE:            POTABLE WATER  
SITE IDENTIFIER: XX708                      DATE RECEIVED: 930809  
DATE COLLECTED: 930730                      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BUDG 708

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.4	mg/L	EPA 200.7
Lead	0.007	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

12 FWS/SGB

APO AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
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REPORT OF ANALYSIS

EASE SAMPLE NO: GP930053      OEHL SAMPLE NO: 93039767  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX750      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BLDG 750

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.9	mg/L	EPA 200.7
Lead	0.018	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

12 FWS/SGB

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930054      OEHL SAMPLE NO: 93039768  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX760      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BLDG 760

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.2	mg/L	EPA 200.7
Lead	0.016	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

12 FWS/SGB

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930055      OEHL SAMPLE NO: 93039769  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX837      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BLDG 837

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	<0.1	mg/L	EPA 200.7
Lead	<0.001	mg/L	EPA 239.2

Comments:

< - Signifies none detected and the detection limits.

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
Special Projects Function

TO:

12 FWS/SGB

APO AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP930056      OEHL SAMPLE NO: 93039770  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XX014      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

BLDG 1400

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.2	mg/L	EPA 200.7
Lead	0.010	mg/L	EPA 239.2

Reviewed by: Leo J. Jehl Jr.  
Chemist, GS-13  
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TO:

12 FWS/SGB

APO AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
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REPORT OF ANALYSIS

BASE SAMPLE NO: GP930057      OEHL SAMPLE NO: 93039771  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 930809  
DATE COLLECTED: 930730      DATE REPORTED: 930910  
DATE ANALYZED: 930831  
SAMPLE SUBMITTED BY: 12 FWS/SGB

---

*CRESCENT LAKE*      RESULTS

---

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	<0.1	mg/L	EPA 200.7
Lead	<0.001	mg/L	EPA 239.2

Comments:

< - Signifies none detected and the detection limits.

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TO:

12 FWS/SGB

APO AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
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WINTER

Cu & Pb

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940109

OEHL SAMPLE NO: 94005229

SAMPLE TYPE: POTABLE WATER

SITE IDENTIFIER: XXXXX

DATE RECEIVED: 940211

DATE COLLECTED: 940202

DATE REPORTED: 940217

DATE ANALYZED: 940216

97

RESULTS

Test	Results	Units	Method
Copper	0.08	mg/L	EPA 220.1
Lead	0.011	mg/L	EPA 239.2

Comments:

PBCU

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SG8

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940108      OEHL SAMPLE NO: 94005228  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

107 RESULTS

Test	Results	Units	Method
Copper	<0.02	mg/L	EPA 220.1
Lead	<0.001	mg/L	EPA 239.2

Comments:

PBCU

< - Signifies none detected and the detection limits.

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SGB

PAGE 1

APD AE 09/04-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940107      DEHL SAMPLE NO: 94005227  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

115      RESULTS

Test	Results	Units	Method
Copper	0.05	mg/L	EPA 220.1
Lead	<0.001	mg/L	EPA 239.2

Comments:

PBCU

< - Signifies none detected and the detection limits.

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SG8

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940106      DEHL SAMPLE NO: 94005226  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

127

RESULTS

Test	Results	Units	Method
Copper	0.28	mg/L	EPA 220.1
Lead	<0.001	mg/L	EPA 239.2

Comments:

PBCU

< - Signifies none detected and the detection limits.

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TO:

12 FWS/SG8

PAGE 1

APD AE 09704-5000

AL/DEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940101      OEHL SAMPLE NO: 94005221  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

245

RESULTS

Test	Results	Units	Method
Copper	0.25	mg/L	EPA 220.1
Lead	0.018	mg/L	EPA 239.2

Comments:

PBCU  
LEAD EXCEEDS MCL OF 0.015 MG/L PER EPA REGULATION.  
DUPLICATE ANALYSIS PERFORMED.

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SGB

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940100      OEHL SAMPLE NO: 94005220  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

256

RESULTS

Test	Results	Units	Method
Copper	0.12	mg/L	EPA 220.1
Lead	<0.001	mg/L	EPA 239.2

Comments:

PBCU

< - Signifies none detected and the detection limits.

Reviewed by: Gerald R. Wittenbach  
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TO:

12 FWS/SG8

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
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REPORT OF ANALYSIS

BASE SAMPLE NO: GP940102      DEHL SAMPLE NO: 94005222  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

325

RESULTS

Test	Results	Units	Method
Copper	0.08	mg/L	EPA 220.1
Lead	<0.001	mg/L	EPA 239.2

Comments:

PBCU

< - Signifies none detected and the detection limits.

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TO:

12 FWS/SGB

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940113      OEHL SAMPLE NO: 94006423  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940218  
DATE COLLECTED: 940201      DATE REPORTED: 940415  
DATE ANALYZED: 940413

426

RESULTS

<u>Test</u>	<u>Results</u>	<u>Units</u>	<u>Method</u>
Copper	0.027	mg/L	EPA 220.1
Lead	<0.001	mg/L	EPA 239.2

Comments:

< - Signifies none detected and the detection limits.

Reviewed by: Gerald R. Wittenbach  
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TO:

12 FWS/SGS

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
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REPORT OF ANALYSIS

BASE SAMPLE NO: GP940097      DEHL SAMPLE NO: 94009217  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

463

RESULTS

Test	Results	Units	Method
Copper	0.15	mg/L	EPA 220.1
Lead	0.018	mg/L	EPA 239.2

Comments:

PBCU  
LEAD EXCEEDS MCL OF 0.015 MG/L PER EPA REGULATION.  
DUPLICATE ANALYSIS PERFORMED.

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

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12 FWS/SGB

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940095                      OEHL SAMPLE NO: 94005215  
SAMPLE TYPE:        POTABLE WATER  
SITE IDENTIFIER: XXXXX                      DATE RECEIVED: 940211  
DATE COLLECTED: 940202                      DATE REPORTED: 940217  
DATE ANALYZED: 940216

580  
RESULTS

Test	Results	Units	Method
Copper	0.04	mg/L	EPA 220.1
Lead	0.002	mg/L	EPA 239.2

Comments:

PBCU

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TO:

12 FWS/SGB

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
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REPORT OF ANALYSIS

BASE SAMPLE NO: GP940104                      OEHL SAMPLE NO: 94005224  
SAMPLE TYPE:        POTABLE WATER  
SITE IDENTIFIER: XXXXX                      DATE RECEIVED: 940211  
DATE COLLECTED: 940202                      DATE REPORTED: 940217  
DATE ANALYZED: 940216

608

RESULTS

Test	Results	Units	Method
Copper	0.03	mg/L	EPA 220.1
Lead	<0.001	mg/L	EPA 239.2

Comments:

PBCU

< - Signifies none detected and the detection limits.

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12 FWS/SGB

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940110      DEHL SAMPLE NO: 94005230  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

619

RESULTS

Test	Results	Units	Method
Copper	<0.02	mg/L	EPA 220.1
Lead	<0.001	mg/L	EPA 239.2

Comments:

PBCU

< - Signifies none detected and the detection limits.

Reviewed by: Gerald R. Wittenbach  
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TO:

12 FWS/SGB

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940111      DEHL SAMPLE NO: 94005231  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

630

RESULTS

Test	Results	Units	Method
Copper	0.05	mg/L	EPA 220.1
Lead	0.011	mg/L	EPA 239.2

Comments:

PBCU

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SG8

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940099      DEHL SAMPLE NO: 94005219  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

707

RESULTS

Test	Results	Units	Method
Copper	0.06	mg/L	EPA 220.1
Lead	0.007	mg/L	EPA 239.2

Comments:

PBCU

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SGB

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940103      DEHL SAMPLE NO: 94005223  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

708

RESULTS

Test	Results	Units	Method
Copper	0.02	mg/L	EPA 220.1
Lead	0.003	mg/L	EPA 239.2

Comments:

PBCU

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SGB

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940096                      OEHL SAMPLE NO: 94005216  
SAMPLE TYPE:        POTABLE WATER  
SITE IDENTIFIER: XXXXX                      DATE RECEIVED: 940211  
DATE COLLECTED: 940202                      DATE REPORTED: 940217  
DATE ANALYZED: 940216

750                      RESULTS

Test	Results	Units	Method
Copper	0.03	mg/L	EPA 220.1
Lead	0.002	mg/L	EPA 239.2

Comments:

PBCU

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SG8

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940105      DEHL SAMPLE NO: 94005225  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

760

RESULTS

Test	Results	Units	Method
Copper	0.09	mg/L	EPA 220.1
Lead	0.018	mg/L	EPA 239.2

Comments:

PBCU  
LEAD EXCEED MCL OF 0.015 MG/L PER EPA REGULATION.  
DUPLICATE ANALYSIS PERFORMED.

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SGB

APD AE 09704-5000

PAGE 1

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940098                      DEHL SAMPLE NO: 94005218  
SAMPLE TYPE:        POTABLE WATER  
SITE IDENTIFIER: XXXXX                      DATE RECEIVED: 940211  
DATE COLLECTED: 940202                      DATE REPORTED: 940217  
DATE ANALYZED: 940216

774

RESULTS

Test	Results	Units	Method
Copper	0.64	mg/L	EPA 220.1
Lead	0.018	mg/L	EPA 239.2

Comments:

PBCU  
LEAD EXCEEDS MCL OF 0.015 MG/L PER EPA REGULATION.  
DUPLICATE ANALYSIS PERFORMED.

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SGB

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940093      OEHL SAMPLE NO: 94005213  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

801

RESULTS

Test	Results	Units	Method
Copper	0.22	mg/L	EPA 220.1
Lead	0.022	mg/L	EPA 239.2

Comments:

PBCU  
LEAD EXCEEDS MCL OF 0.015 MG/L PER EPA REGULATION.  
DUPLICATE ANALYSIS PERFORMED.

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SG8

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940094      OEHL SAMPLE NO: 94005214  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

836

RESULTS

Test	Results	Units	Method
Copper	0.04	mg/L	EPA 220.1
Lead	0.003	mg/L	EPA 239.2

Comments:

PBCU

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SGB

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940092                      OEHL SAMPLE NO: 94005212  
SAMPLE TYPE:        POTABLE WATER  
SITE IDENTIFIER: XXXXX                      DATE RECEIVED: 940211  
DATE COLLECTED: 940202                      DATE REPORTED: 940217  
DATE ANALYZED: 940216

935

RESULTS

Test	Results	Units	Method
Copper	0.02	mg/L	EPA 220.1
Lead	<0.001	mg/L	EPA 239.2

Comments:

PBCU

< - Signifies none detected and the detection limits.

Reviewed by: Gerald R. Wittenbach  
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TO:

12 FWS/SG8

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940112      DEHL SAMPLE NU: 94005232  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

1400

RESULTS

Test	Results	Units	Method
Copper	<0.02	mg/L	EPA 220.1
Lead	0.018	mg/L	EPA 239.2

Comments:

PBCU

LEAD EXCEEDS MCL OF 0.015 MG/L PER EPA REGULATION.

DUPLICATE ANALYSIS PERFORMED.

< - Signifies none detected and the detection limits.

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SGB

PAGE 1

APD AE 09704-5000

AL/OEA  
2402 E DRIVE  
BROOKS AFB, TEXAS, 78235-5114

REPORT OF ANALYSIS

BASE SAMPLE NO: GP940114      DEHL SAMPLE NO: 94005233  
SAMPLE TYPE:      POTABLE WATER  
SITE IDENTIFIER: XXXXX      DATE RECEIVED: 940211  
DATE COLLECTED: 940202      DATE REPORTED: 940217  
DATE ANALYZED: 940216

---

LAKE CRESCENT RESULTS

---

Test	Results	Units	Method
Copper	<0.02	mg/L	EPA 220.1
Lead	<0.001	mg/L	EPA 239.2

Comments:

PBCU

< - Signifies none detected and the detection limits.

Reviewed by: Gerald R. Wittenbach  
Chief, Environmental Metals Function

TO:

12 FWS/SSB

APD AE 09704-5000

PAGE 1

GREENLAND CONTRACTORS  
Thule Air Base  
Environmental Engineering Group  
Thyge Færch/amk



20 September 1994  
GC/EEG  
FY94-762

Total number of pages: 8

TELEFAX

Pacific Environmental Services, INC  
560 Herndon Parkway, Suite 200  
Herndon, VA 22070

Fax: (703) 481-8296

*For Wayne  
Westbrook*

Attn.: Robert Forbes

GC-121, Contract No. F61101-91-C-0003

Potable Water Survey Performed for USAF, 21 SPW Bioenvironmental Section.

Reference is made to our telephone conversation on 16 September, subject as above.

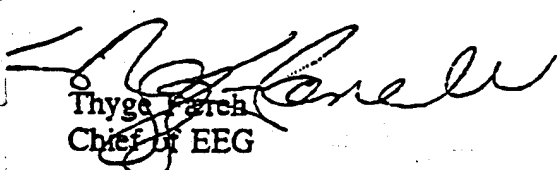
Enclosed please find:

- Sampling results from Lead and Copper non-compliance tests, July 1993 to July 1994. Note that the sampling locations were changed in order to better reflect the entire installation in February 1994.
- Saturation index was calculated for a sample, collected at the main entrance base potable water system, according to "Standard Methods for the Examination of Water and Wastewater", 17th edition 1989: 2330 Calcium Carbonate Saturation (Approved by Standard Methods Committee, 1989).

Please be informed that phosphate, in the raw water as well as in the treated water, is below our detection limit of 0.1 ppm. The temperature of the raw water has previously been reported to 21 SPW, Bioenvironmental Section.

In the event you should have any questions, or if further clarification is required, please do not hesitate to call the undersigned at + 299-50636 ext. 2698.

Sincerely,

  
Thyge Færch  
Chief of EEG

c.c.: 12 SWS/LG

**Thule Lead and Copper non-compliance tests  
July 1993 July 1994**

Lead tests: Action Level 0.015 mg/L as 90th percentile.

Detection limit for Lead is 0.001 mg/L, although results of 0.001 mg/L may contain less.

Fac.	Lead 07/93	Lead 02/94	Lead 07/94
0097	0.003	0.011	0.055
0107	0.001	0.001	0.001
0115	0.003	0.001	0.003
0127	0.001	0.001	0.001
0245		0.018	0.020
0256		0.001	0.001
0325		0.001	0.001
0463		0.018	0.022
0580		0.002	0.028
0608	0.006	0.001	0.002
0619		0.001	0.001
0630		0.011	0.002
0707		0.021	0.002
0708	0.007	0.003	0.016
0750	0.018	0.002	0.011
0760	0.016	0.018	0.012
0774		0.018	
0801	0.001	0.022	0.007
0836		0.003	0.012
0935		0.001	0.065
1400	0.010	0.018	0.010
Test result	0.051	0.018	0.028

Comment: Tests sampled 07/93 were collected at locations different from the samplings 02/94 and 07/94

Copper tests: Action Level 1.3 mg/L as 90th percentile.

Detection limit for Copper is 0.02 mg/L, although results of 0.02 mg/L may contain less, except for Bldg #935 where the specific result of 0.014 mg/L for some reason is given.

Fac.	Copper 0793	Copper 0294	Copper 0794
0097	1.5	0.08	0.12
0107	0.1	0.02	0.020
0115	0.8	0.05	0.08
0127	1.5	0.28	0.20
0245		0.25	0.23
0256		0.12	0.062
0325		0.08	0.064
0463		0.15	0.133
0580		0.04	0.062
0608	0.2	0.03	0.030
0619		0.02	0.020
0630		0.05	0.039
0707		0.6	0.032
0708	0.4	0.02	0.058
0750	0.9	0.03	0.020
0760	0.27	0.09	0.064
0774		0.64	
0801	0.1	0.22	0.158
0836		0.04	0.148
0935		0.02	0.014
1400	0.2	0.02	0.020
Test result	1.5	0.28	0.158

Comment: Tests sampled 07/93 were collected at locations different from the samplings of 02/94 and 07/94.

Thyge Færch,  
12 september 1994

## SATURATION INDEX

SAMPLE NUMBER: /DATE: 17 SEP 93

Measurements: Temperature : 9 °C  
 pH (temp adj.) : 6.6

	MÅLINGER	BEREGNINGER	
Conductivity	90 umhos/cm=z	$I = z \cdot 1,6 \cdot 10^{-5}$	$I = 1,44 \cdot 10^{-3}$
Calcium	30 ppm=x	$X = x/40,1 \cdot 10^3$	$-\log X = 3,13 = p[Ca]$
Alkalinity	16 ppm=y	$Y = y/61,0 \cdot 10^3$	$-\log Y = 3,58 = p[HCO_3]$

TABLE 2330.II. PRECALCULATED VALUES FOR  $pK$  AND  $A$  AT SELECTED TEMPERATURES

Temperature °C	$pK_2$	$pK_1$			$pK_w$	$A$
		Calcite	Aragonite	Vaterite		
5	10.55	8.39	8.24	7.77	14.73	0.494
10	10.49	8.41	8.26	7.80	14.53	0.498
15	10.43	8.43	8.28	7.84	14.34	0.502
20	10.38	8.45	8.31	7.87	14.16	0.506
25	10.33	8.48	8.34	7.91	13.99	0.511
30	10.29	8.51	8.37	7.96	13.83	0.515
35	10.25	8.54	8.41	8.00	13.68	0.520
40	10.22	8.58	8.45	8.05	13.53	0.526
45	10.20	8.62	8.49	8.10	13.39	0.531
50	10.17	8.66	8.54	8.16	13.26	0.537
60	10.14	8.76	8.64	8.28	13.02	0.549
70	10.13	8.87	8.75	8.40	—	0.562
80	10.13	8.99	8.88	8.55	—	0.576
90	10.14	9.12	9.02	8.70	—	0.591

NOTE: All values determined from the equations of Table 2330.I

$$pK_2 = 10.50 \quad pK_1 = 8.41 \text{ (calcite)} \quad pK_w = 14.57 \quad A = 0.497$$

$$pf_a = A \cdot \frac{\sqrt{I}}{1 + \sqrt{I}} + (0.3 \cdot I) = 0.0177$$

$$I_s = pK_2 + pK_1 + p[Ca] + p[HCO_3] + 5 pf_a = 8.89$$

$$SI = pH - pH_s = -2.3$$

## SATURATION INDEX

SAMPLE NUMBER: 2DATE: 17 SEP 93

Measurements: Temperature : 9 °C  
 pH (temp adj.) : 6.8

	MÄLINGER	BEREGNINGER	
Conduktivitet	90 umhos/cm=z	$I = z \cdot 1,6 \cdot 10^{-5}$	$I = 1,44 \cdot 10^{-3}$
Calcium	35 ppm=x	$X = x/40,1 \cdot 10^3$	$-\log X = 3,06 = p[Ca]$
Alkalinity	18 ppm=y	$Y = y/61,0 \cdot 10^3$	$-\log Y = 3,53 = p[HCO_3]$

TABLE 2330:IL PRECALCULATED VALUES FOR  $pK$  AND  $A$  AT SELECTED TEMPERATURES

Temperature °C	$pK_i$				$pK_a$	$A$
	$pK_1$	Calcite	Aragonite	Vaterite		
5	10.55	8.39	8.24	7.77	14.73	0.494
10	10.49	8.41	8.26	7.80	14.53	0.498
15	10.43	8.43	8.28	7.84	14.34	0.502
20	10.38	8.45	8.31	7.87	14.16	0.506
25	10.33	8.48	8.34	7.91	13.99	0.511
30	10.29	8.51	8.37	7.96	13.83	0.515
35	10.25	8.54	8.41	8.00	13.68	0.520
40	10.22	8.58	8.45	8.05	13.53	0.526
45	10.20	8.62	8.49	8.10	13.39	0.531
50	10.17	8.66	8.54	8.16	13.26	0.537
60	10.14	8.76	8.64	8.28	13.02	0.549
70	10.13	8.87	8.75	8.40	—	0.562
80	10.13	8.99	8.88	8.55	—	0.576
90	10.14	9.12	9.02	8.70	—	0.591

NOTE: All values determined from the equations of Table 2330:1.

$$pK_2 = 10.50 \quad pK_1 = 8.41 \text{ (calcite)} \quad pK_a = 14.57 \quad A = 0.497$$

$$pf_a = A \cdot \frac{\sqrt{I}}{1 + \sqrt{I}} + (0.3 \cdot I) = 0.0177$$

$$H_s = pK_2 + pK_1 + p[Ca] + p[HCO_3] + 5 pf_a = 8.77$$

$$SI = pH - pH_s = -2.0$$

## SATURATION INDEX

SAMPLE NUMBER: 3DATE: 17 SEP 93

Measurements: Temperature : 9 °C  
 pH (temp adj.) : 6.9

	MÄLINGER	BEREGNINGER	
Conduktivitet	90 umhos/cm=z	$I = z \cdot 1,6 \cdot 10^{-5}$	$I = 1,44 \cdot 10^{-3}$
Calcium	35 ppm=x	$X = x/40,1 \cdot 10^3$	$-\log X = 3,06 = p[Ca]$
Alkalinity	18 ppm=y	$Y = y/61,0 \cdot 10^3$	$-\log Y = 3,55 = p[HCO_3]$

TABLE 2330-II. PRECALCULATED VALUES FOR  $pK$  AND  $A$  AT SELECTED TEMPERATURES

Temperature °C	$pK_1$				$pK_2$	$A$
	$pK_1$	Calcite	Aragonite	Vaterite		
5	10.55	8.39	8.24	7.77	14.73	0.494
10	10.49	8.41	8.26	7.80	14.53	0.498
15	10.43	8.43	8.28	7.84	14.34	0.502
20	10.38	8.45	8.31	7.87	14.16	0.506
25	10.33	8.48	8.34	7.91	13.99	0.511
30	10.29	8.51	8.37	7.96	13.83	0.515
35	10.25	8.54	8.41	8.00	13.68	0.520
40	10.22	8.58	8.45	8.05	13.53	0.526
45	10.20	8.62	8.49	8.10	13.39	0.531
50	10.17	8.66	8.54	8.16	13.26	0.537
60	10.14	8.76	8.64	8.28	13.02	0.549
70	10.13	8.87	8.75	8.40	—	0.562
80	10.13	8.99	8.88	8.55	—	0.576
90	10.14	9.12	9.02	8.70	—	0.591

NOTE: All values determined from the equations of Table 2330-I.

$$pK_2 = 10.50 \quad pK_1 = 8.41 \text{ (calcite)} \quad pK_2 = 14.57 \quad A = 0.497$$

$$pf_n = A \cdot \frac{\sqrt{I}}{1 + \sqrt{I}} + (0.3 \cdot I) = 0.0177$$

$$pH_s = pK_1 + pK_2 + p[Ca] + p[HCO_3] + 5 pf_n = 8.77$$

$$SI = pH - pH_s = -1.9$$

## SATURATION INDEX

SAMPLE NUMBER: 4DATE: 17 SEP 93
 Measurements: Temperature : 9 °C  
 pH (temp adj.) : 6.9

	MÄLINGER	BEREGNINGER
Conduktivity	90 umhos/cm = z	$I = z \cdot 1.6 \cdot 10^{-5}$ $I = 1.44 \cdot 10^{-3}$
Calcium	35 ppm = x	$X = x / 40.1 \cdot 10^3$ $-\log X = 3.06 = p[Ca]$
Alkalinity	16 ppm = y	$Y = y / 61.0 \cdot 10^3$ $-\log Y = 3.58 = p[HCO_3]$

TABLE 2330:II. PRECALCULATED VALUES FOR  $pK$  AND  $A$  AT SELECTED TEMPERATURES

Temperature °C	$pK_2$	$pK_1$			$pK_a$	$A$
		Calcite	Aragonite	Valerite		
5	10.55	8.39	8.24	7.77	14.73	0.494
10	10.49	8.41	8.26	7.80	14.53	0.498
15	10.43	8.43	8.28	7.84	14.34	0.502
20	10.38	8.45	8.31	7.87	14.16	0.506
25	10.33	8.48	8.34	7.91	13.99	0.511
30	10.29	8.51	8.37	7.96	13.83	0.515
35	10.25	8.54	8.41	8.00	13.68	0.520
40	10.22	8.58	8.45	8.05	13.53	0.526
45	10.20	8.62	8.49	8.10	13.39	0.531
50	10.17	8.66	8.54	8.16	13.26	0.537
60	10.14	8.76	8.64	8.28	13.02	0.549
70	10.13	8.87	8.75	8.40	—	0.562
80	10.13	8.99	8.88	8.55	—	0.576
90	10.14	9.12	9.02	8.70	—	0.591

NOTE: All values determined from the equations of Table 2330:I

$$pK_2 = 10.50 \quad pK_1 = 8.41 \text{ (calcite)} \quad pK_a = 14.53 \quad A = 0.497$$

$$pf_a = A \cdot \frac{\sqrt{I}}{1 + \sqrt{I}} + (0.3 \cdot I) = 0.0177$$

$$p_s = pK_2 + pK_a + p[Ca] + p[HCO_3] + 5 pf_a = 8.82$$

$$SI = pH - p_s = -1.9$$

## SATURATION INDEX

SAMPLE NUMBER: 5DATE: 17 SEP 93
 Measurements: Temperature : 9 °C  
 pH (temp adj.) : 6.9

	MÄLINGER	BEREGNINGER	
Conduktivität	90 umhos/cm = z	$I = z \cdot 1,6 \cdot 10^{-5}$	$I = 1,44 \cdot 10^{-3}$
Calcium	35 ppm = x	$X = x / 40,1 \cdot 10^3$	$-\log X = 3,06 = p[Ca]$
Alkalinity	16 ppm = y	$Y = y / 61,0 \cdot 10^3$	$-\log Y = 3,58 = p[HCO_3]$

TABLE 2330:II. PRECALCULATED VALUES FOR  $pK$  AND  $A$  AT SELECTED TEMPERATURES

Temperature °C	$pK_1$	$pK_2$			$pK_a$	$A$
		Calcite	Aragonite	Vaterite		
5	10.55	8.39	8.24	7.77	14.73	0.494
10	10.49	8.41	8.26	7.80	14.53	0.498
15	10.43	8.43	8.28	7.84	14.34	0.502
20	10.38	8.45	8.31	7.87	14.16	0.506
25	10.33	8.48	8.34	7.91	13.99	0.511
30	10.29	8.51	8.37	7.96	13.83	0.515
35	10.25	8.54	8.41	8.00	13.68	0.520
40	10.22	8.58	8.45	8.05	13.53	0.526
45	10.20	8.62	8.49	8.10	13.39	0.531
50	10.17	8.66	8.54	8.16	13.26	0.537
60	10.14	8.76	8.64	8.28	13.02	0.549
70	10.13	8.87	8.75	8.40	—	0.562
80	10.13	8.99	8.88	8.55	—	0.576
90	10.14	9.12	9.02	8.70	—	0.591

NOTE: All values determined from the equations of Table 2330:I

$$pK_1 = 10,50 \quad pK_2 = 8,41 \text{ (calcite)} \quad pK_a = 14,57 \quad A = 0,497$$

$$pf_a = A \cdot \frac{\sqrt{I}}{1 + \sqrt{I} + (0.3 \cdot I)} = 0,0177$$

$$pH_s = pK_1 + pK_a + p[Ca] + p[HCO_3] + 5 pf_a = 8,82$$

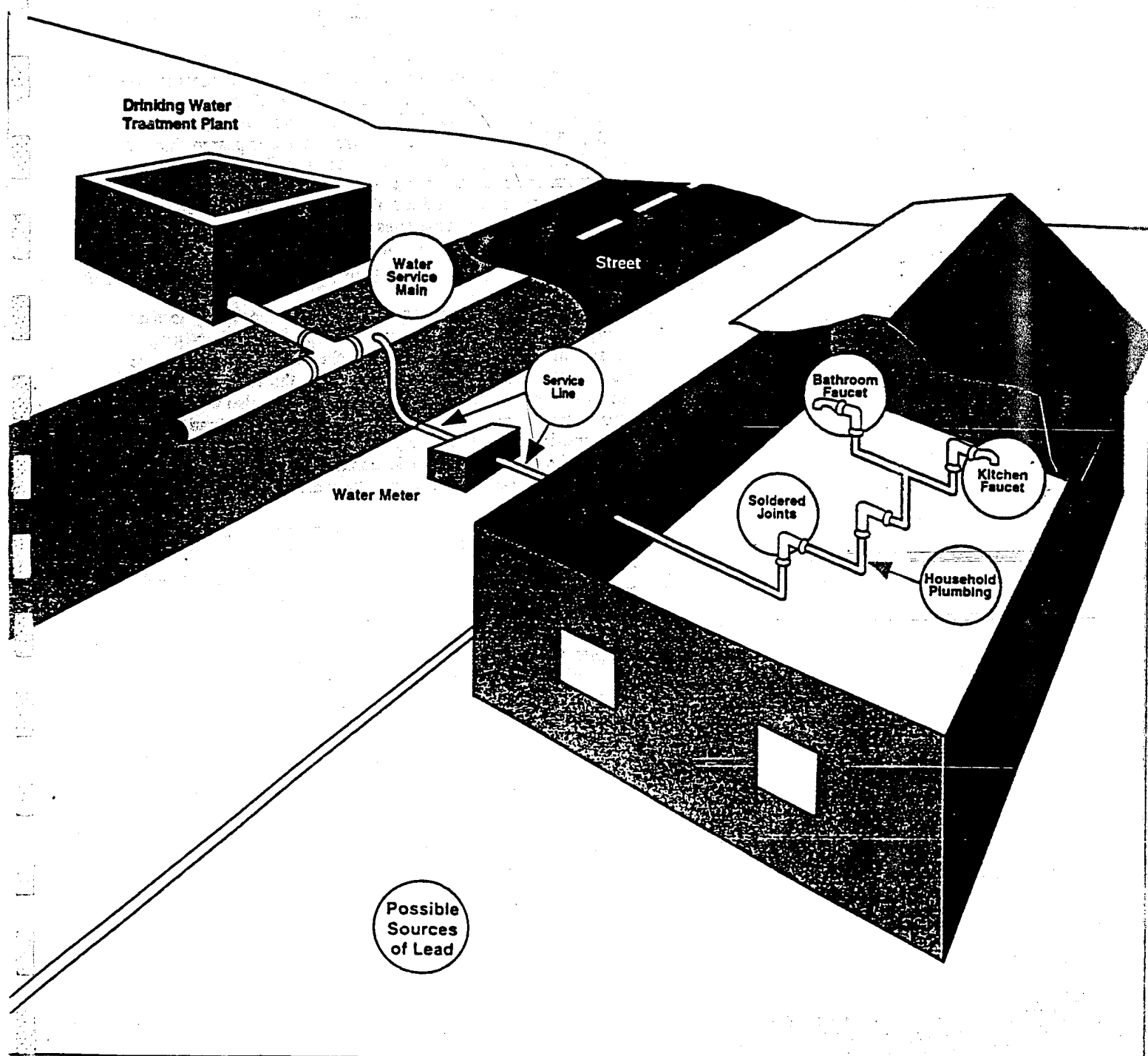
$$SI = pH - pH_s = -1,9$$

## APPENDIX D



# Seminar Publication

## Control of Lead and Copper in Drinking Water



### 5.3 Full-Scale Performance Testing of Sodium Silicate to Control the Corrosion of Lead, Copper, and Iron: York, Maine

#### 5.3.1 Introduction

In Summer 1991, the York Water District (YWD) in Maine placed a 4 million gallons per day (mgd) water treatment facility into service to provide coagulation, clarification, filtration, and disinfection of its surface water supply. The plant was designed to meet the requirements of the SWTR. In common with other surface water treatment plants in New England, the water produced by the plant is soft ( $\text{Ca} < 1 \text{ mg/L}$ ), low in alkalinity ( $< 10 \text{ mg/L}$  as  $\text{CaCO}_3$ ), and has a moderately high pH (8.3 to 8.8). As this generally corrosive water passed through the distribution system, it picked up significant quantities of iron from unlined cast iron pipe. Consumers served from cast iron water mains complained of a red water problem. Samples were collected from these sites to verify the presence of iron, and the iron concentration in these samples ranged from 0.4 to 1.9 mg/L.

Although the plant was designed with the ability to feed polyphosphate to control the red water problems, the appropriateness of this and other treatment chemicals was reviewed to address the anticipated requirements of the lead and copper rule. Zinc orthophosphate and silicate addition also were evaluated as treatment strategies. Calcium carbonate saturation was not considered a feasible or practical option, because it would involve the construction of additional feed systems to introduce both calcium and carbonate into the water.

Polyphosphates, although well-known for their ability to control red water problems by sequestering iron, were deemed inappropriate as a method to control lead- and copper-based corrosion. To control iron, polyphosphates generally require a pH in the 7.2 to 7.6 range, which is not optimal for control of lead or copper. Furthermore, polyphosphates have the ability to complex with lead and copper, potentially causing the concentration of these metals to increase (7). Zinc orthophosphate was considered for its ability to control lead by forming sparingly soluble lead orthophosphate films (14), but it is unable to provide a mechanism for control of iron corrosion. Also, there was concern that the zinc would be concentrated in the sludge generated by the community wastewater treatment facility. The use of sodium silicate reportedly has been a common strategy for low-hardness waters and has been favored for its potential to form a surficial coating on piping systems (15). In addition, silicate has a large capacity to disperse iron colloids, thus masking the red water problems (16). Several utilities in Maine with low alkalinity ( $< 15 \text{ mg/L}$  as  $\text{CaCO}_3$ ) and low hardness ( $< 5 \text{ mg/L}$  as  $\text{CaCO}_3$ ) have reported that sodium silicate was extremely effective in eliminating red water complaints. An advantage of silicates over polyphosphates is the pH range in

which each inhibitor is effective for control of red water problems. Polyphosphates can sequester iron at a pH generally <7.5, whereas silicates are effective in controlling red water problems at a higher pH (>8). The higher pH that can be used with silicate treatment is also more appropriate for controlling the dissolution of lead and copper. A well-known advantage associated with sodium silicate is that it does not contain zinc. Based on these considerations and system constraints, sodium silicate was recommended for full-scale performance testing.

With assistance from an engineering firm, the YWD designed a water quality monitoring program to track metal concentrations in response to the addition of sodium silicate over an extended period of time (18 months). Twelve sampling sites were identified throughout the distribution system to account for spatial variations in water quality. All sampling sites were cold water faucets located within buildings. First- and second-draw samples were collected from all 12 sites on the same day every 2 months. The first- and second-draw samples were analyzed for lead, copper, iron, calcium, and silica. A third sample was collected immediately after the second and analyzed for pH and alkalinity. The monitoring data collected over the course of 1991 are discussed in the following sections.

### 5.3.2 Findings

- The finished water produced from the YWD filtration plant without the application of sodium silicate has low alkalinity (8 to 10 mg/L as  $\text{CaCO}_3$ ), moderately high pH (8.3 to 8.8), low turbidity (<0.10 NTU), low color (<10 CU) and is very soft ( $\text{Ca}$  <1 mg/L;  $\text{Fe}$  <0.05 mg/L). The water was corrosive toward lead and iron, as it produced an average lead level of  $83 \pm 145 \mu\text{g/L}$  in first-draw samples and iron levels in the range of  $0.33 \pm 0.55 \text{ mg/L}$  from first- and second-draw samples. The finished water was less corrosive toward copper; the average copper level from first-draw samples was  $0.15 \pm 0.13 \text{ mg/L}$ .
- Periods of 2 to 3 years might be required before the impacts of silicate addition can be determined, due to annual cycles in temperature and flow rate.
- The low buffering capacity of the plant water and variations in the coagulation process resulted in large pH fluctuations in the water exiting the filters. Sodium silicate fed into the filtered water served essentially two functions: to adjust the pH and to add silica to the finished water. As a result, it was extremely difficult for the operator to maintain a constant finished water pH and silica dosage.
- The alkalinity and pH were significantly lower at dead ends of the distribution system, especially when the dead-end lines were unlined cast iron. These areas consistently had lower silica concentrations and higher concentrations of corrosion products.
- Lead levels averaged  $83 \pm 145 \mu\text{g/L}$  during the initial sampling event when sodium hydroxide was being applied to finish the water during December and the first week of January 1991. After feeding sodium silicate in lieu of sodium hydroxide, the average lead levels in first-draw samples de-

creased and stabilized to  $26 \pm 22 \mu\text{g/L}$  during the period of May to December 1991.

- Red water complaints received by the YWD when sodium hydroxide was being fed were eliminated completely with the application of sodium silicate. Iron concentrations in the samples collected throughout the distribution system ranged from 0.10 to 1.9 mg/L before silicate treatment, and from 0.10 to 1.37 mg/L after treatment. It is likely, therefore, that silicate was sequestering iron.
- Iron concentrations showed only a slight reduction over time in response to treatment with silicate.
- Copper levels in the first-draw samples before application of silicate were relatively low, averaging  $0.15 \pm 0.13 \text{ mg/L}$  and ranging from 0.06 to 0.48 mg/L. Application of sodium silicate reduced these levels slightly.
- Silica concentrations decreased as the water passed through the distribution system, suggesting that silica was coating the surface of pipes. Also, the average silica concentration in the first-draw samples was lower during each sampling event than the average silica concentration in the second-draw samples, suggesting that forms of dissolved silica were coating the internal surfaces of plumbing.
- With the average maintenance silica dosage of 11 mg/L used in this evaluation (startup period excluded), the chemical cost to the YWD is \$8.12 per million liters.

### 5.3.3 Recommendations

- If silicates are used to control corrosion in soft, low-alkalinity waters, careful consideration must be given to the design of feed systems to ensure that a constant dosage of silica is provided. Therefore, it might be necessary in certain situations to adjust pH separately by the addition of another chemical, such as potassium or sodium hydroxide.
- In water with low alkalinity (<10 mg/L as  $\text{CaCO}_3$ ), the use of silicates in conjunction with carbonate (alkalinity increase) adjustment should be investigated. Alkalinity could be supplied by silicates as long as the pH is raised into the 9.0 to 10.0 range. Increasing the alkalinity would minimize the pH reductions that occurred at the ends of the system.
- Studies should be conducted under controlled conditions to determine relationships among hardness, DIC, pH, existing films, silica dosage, and effectiveness of treatment.
- Full-scale water quality monitoring programs aimed at determining the effectiveness of silicate addition should be performed over a period of several years.
- When silicates are used as a means of corrosion control, pH, alkalinity, and silica levels should be monitored at the extremities of the distribution system.

### 5.3.4 Methodology

#### 5.3.4.1 Description of the Facilities

The source of water for the YWD is a shallow (<10 m) pond. The facilities that process the water are an intake facility at the shore of the pond and a filtration facility. Water flows by gravity from the intake facility to the filtration facility. Although the intake facility contains equipment to permit addition of chlorine and potassium permanganate, these chemicals are not routinely added.

Water entering the filtration facility is injected with aluminum sulfate and sodium hydroxide for coagulation. After being coagulated, the water enters an upflow clarifier, consisting of plastic media retained by a stainless steel screen. The media retain a portion of the coagulated material, and the remaining residual particulate matter is retained on a mixed-media filter. Water exiting the mixed-media filter is chlorinated for disinfection before it enters a 300,000-gallon contact basin/clearwell. The pH of the disinfected water exiting the clearwell is raised to between 8.3 and 8.8, prior to the addition of ammonia gas, to maximize the formation potential of monochloramine. When the trial application of sodium silicate was initiated, it was fed through the sodium hydroxide feed system.

The distribution system consists of approximately 40 percent unlined cast iron pipe and 60 percent cement-lined cast and ductile iron pipe. The unlined cast iron pipe is approximately 50 to 100 years old. There are no known lead service lines or asbestos-cement pipe in the system. York is a coastal tourist community with the population served by the YWD ranging from 5,000 in the winter to approximately 10,000 in the summer. The large population fluctuation causes the average daily flow rate to range from approximately 1.3 mgd in the winter to 3 mgd in the summer.

#### 5.3.4.2 Study Objective

The objective of the evaluation was to determine the effectiveness of sodium silicate in controlling iron, lead, and copper corrosion in the YWD's distribution system and within residential home plumbing systems. Effectiveness, in this case, means noticeable reductions in the concentrations of the referenced corrosion products over a period of 18 months. This report covers data collected over the first 12 months of monitoring.

#### 5.3.4.3 Treatment Scheme

The sodium silicate solution used in the evaluation was Type N<sup>®</sup> (PQ Corporation, Philadelphia, PA), which has a silica (SiO<sub>2</sub>) to sodium oxide (Na<sub>2</sub>O) ratio of 3.22:1. It was selected because it was the least expensive available silicate solution in the region and because it has a relatively high SiO<sub>2</sub>:Na<sub>2</sub>O ratio.

The silicate dosages used in this evaluation were based on recommendations from the manufacturer and on information available in the literature (15,17). The goal was to follow the present practice of applying silica to control corrosion in water distribution systems. Over the first 2 months of the monitoring program, a silica dosage of 16 to 20 mg/L as SiO<sub>2</sub> was used. For the remainder of the monitoring program, the silica dosage was lowered to 8 to 12 mg/L as SiO<sub>2</sub>.

#### 5.3.4.4 Monitoring Program Design

The main objective of the monitoring program was to generate sufficient data to determine the effectiveness of sodium silicate in reducing levels of principal corrosion products, including lead, copper, and iron. Another goal was to gain an understanding of the potential mechanism of silicate corrosion inhibition (e.g., surficial coating) by monitoring silica concentrations throughout the distribution system. To meet these objectives effectively, a monitoring program was designed to track pH, alkalinity, calcium, lead, copper, and iron levels at 12 points throughout the distribution system over an 18-month period. Sampling events consisted of collecting three samples from each monitoring location on the same day.

Because water system personnel could gain regular entrance to only a limited number of buildings, a survey was conducted to identify and select individual homeowners to participate in the monitoring program. The selection of sites was based on the ability of the participating residents to understand and perform the prescribed sampling procedures effectively for the period of the monitoring program. In addition, the locations were apportioned throughout the distribution system, covering both the center and the ends of the distribution system (Figure 5-15). An extensive materials survey to identify specific sampling locations based on sources of lead and copper was not performed prior to the monitoring program.

In York, annual cycles in water flow through the distribution system and in temperature represent important temporal variations. It was necessary, therefore, to monitor water quality changes over a period of 18 months. Sampling was conducted every 2 months to account for changes in flow and temperature.

#### 5.3.4.5 Sampling and Analytical Procedures

**Sampling Procedures.** First-draw and second-draw samples were collected from taps from 12 buildings throughout the distribution system (Figure 5-15). First-draw samples were collected after the water was allowed to stand motionless for 6 to 12 hours. Second-draw samples were collected after the tap had been flushed for a period of 5 minutes. The first- and second-draw samples were collected in 250 mL bottles, and each was analyzed for lead, copper, iron, calcium, and silica. A third 250-mL sample was collected immediately after the second-draw sample and was analyzed for pH and alkalinity. The three samples were collected on the same day from each of the 12 sites to relate metal concentrations to the referenced water quality parameters.

**pH and Alkalinity.** Samples for pH and alkalinity were measured in the laboratory within 24 hours of the time of collection. The pH was measured with an ORION SA250 pH meter. The meter was calibrated with pH buffer standards at pH 4, 7, and 10. The meter was recalibrated at the end of a group of analyses to check for instrumental drift. Alkalinity was determined by EPA (1983) Method No. 310.1 using 0.02 N H<sub>2</sub>SO<sub>4</sub>.

**Lead, Iron, Calcium, and Copper.** Upon arrival at the laboratory, samples for lead were acidified to pH <2 with concentrated nitric acid. Lead samples were analyzed on a Perkin

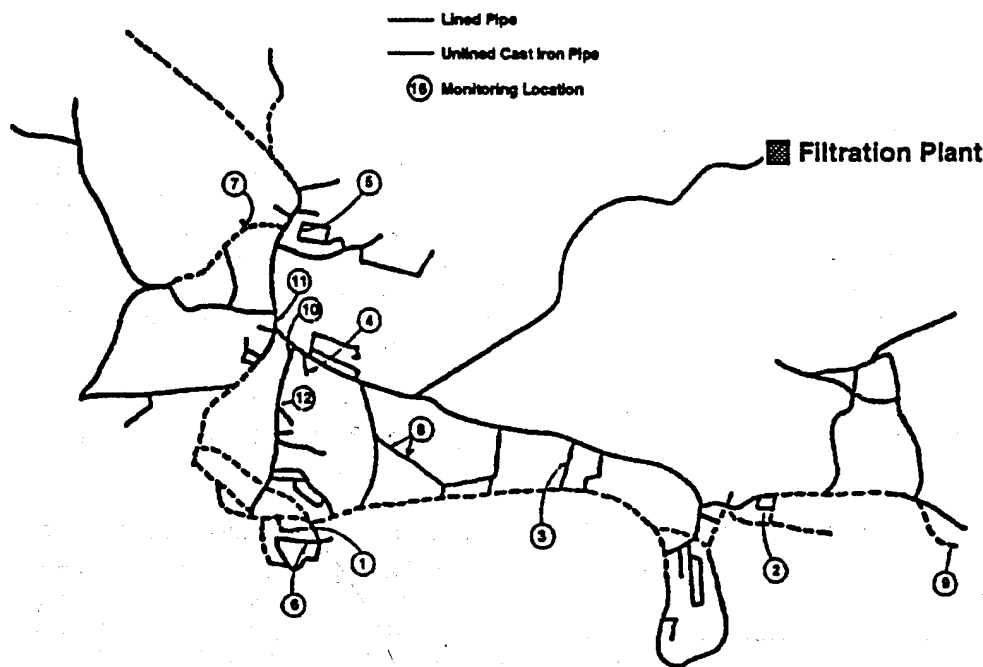


Figure 5-15. Map of the York Water District distribution system.

Elmer 5100 PC Atomic Absorption Graphite Furnace according to Standard Methods (1989) No. 3113 B. Samples for iron, calcium, and copper were analyzed on a Perkin Elmer Model No. 460 Flame Atomic Absorption Spectrophotometer, according to Standard Methods No. 3500 B. Field spikes and blanks were performed during each analysis to determine the accuracy of the method.

**Silica.** Silica analyses were conducted using Inductively Coupled Plasma (ICP) according to EPA (1983) Method No. 200.7.

**Data Analysis.** In the case of small sets of data, including outliers can result in a bias in the calculated mean. Therefore, sets of lead data from every sampling event were subjected to the Dixon Test to eliminate outliers.

### 5.3.5 Results and Discussion

The data collected for the evaluation of silicates are presented in the following two sections. First, treatment plant operating data over the 12-month period are discussed. Second, the results of the distribution system monitoring program are presented.

#### 5.3.5.1 Plant Operating Data

**Finished Water Quality Data.** Table 5-2 summarizes the average annual finished water characteristics at the YWD filtration facility during the monitoring period. In general, the water is corrosive toward lead and iron due to its low alkalinity. With the exception of temperature, the finished water quality parameters do not vary significantly on a weekly or annual basis.

Table 5-2. Average Finished Water Quality Summary

Parameter	Mean	Standard Deviation
pH	8.5	±0.29
Alkalinity (mg/L as CaCO <sub>3</sub> )	8.0	±1.65
Turbidity (NTU)	0.06	±0.01
Temperature (°C)	13.0	±3.0
Iron (mg/L)	0.03	±0.01
Manganese (mg/L)	0.06	±0.02
Aluminum (mg/L)	0.05	±0.04

**Temperature.** Temperature can have a pronounced effect on the rate of corrosion. In general, as the temperature increases, so does the corrosion rate of most materials. As illustrated in Figure 5-16a, the temperature in the finished water increased from 4°C during the winter to 24°C in the summer months. Therefore, the rate of corrosion due to temperature effects would be highest in the summer months.

**Flow Rate.** The average velocity of the water carried through a distribution system should increase, in general, as plant flow rate (output) increases. Velocity is an important physical factor that affects the rate of corrosion. Slow velocities within a distribution system cause water to be stagnant; often a marked decrease or increase in pH is observed. Velocity, as it relates to inhibitor-based corrosion control, is important in sustaining a passivating film on a pipe surface. As velocity increases, so does the rate at which a given mass of inhibitor comes in contact with a given unit surface area of pipe.

The quantity of water produced varied significantly from winter to summer (Figure 5-16b), due to seasonal population patterns. This variation had a tendency to cause stagnant areas during the winter months, which resulted in lower pH values at dead-end monitoring locations.

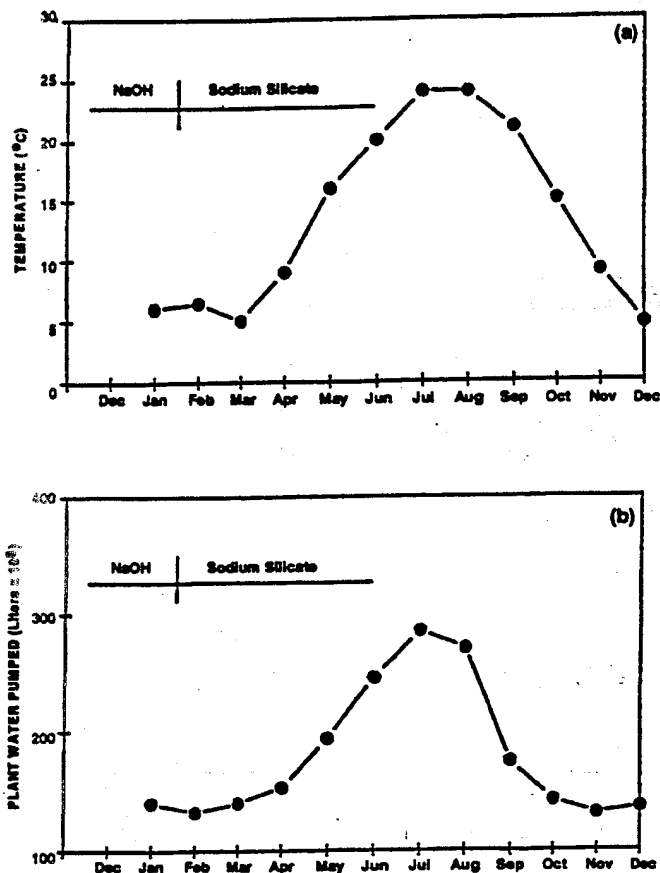


Figure 5-16. Temperature of the filtration plant finished water (a) and monthly water production (b).

**Silica Dosage.** The monthly average silica dosage and raw water silica concentrations over the course of a 12-month monitoring period are presented in Figure 5-17. The average silica dosages were determined by dividing the total volume of silica

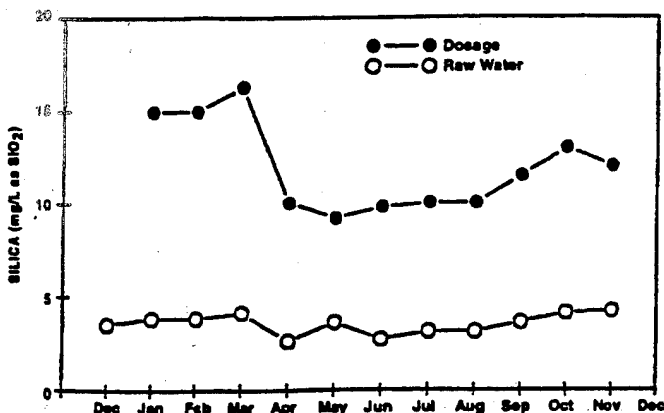


Figure 5-17. Average monthly silica dosages and raw water silica concentrations.

applied by the volume of finished water pumped. The silica dosages used in this evaluation (9 to 16 mg/L) were similar to dosages (12 to 20 mg/L) at a nearby utility with similar water quality conditions.

After reviewing the distribution system data in August, it was noted that the pH at remote points in the distribution system was low (<7.2). To raise the pH at these locations, the feed rate of sodium silicate was increased in September and October. As a result, the silica dosage increased (Figure 5-17) over the same time period. The sodium silicate solution, therefore, was performing two functions: to raise the pH of, and to add silica to, the plant finished water. The operating data suggest that the feasibility of feeding a more alkaline sodium silicate solution (lower SiO<sub>2</sub>:Na<sub>2</sub>O ratio) or accomplishing pH adjustment separately with another chemical, such as sodium or potassium hydroxide, should be investigated.

### 5.3.5.2 Distribution System Monitoring Data

**pH.** During the period when the finished water was adjusted with sodium hydroxide, prior to application of sodium silicate, the average pH from the monitoring points was  $8.34 \pm 0.26$ . When the average startup dosage of approximately 16 to 20 mg/L as SiO<sub>2</sub> was being administered, the pH from the sites averaged  $8.38 \pm 0.14$ . After the initial startup dosage was lowered to a maintenance dosage of 10 mg/L as SiO<sub>2</sub> during late March, the pH dropped to an average of  $7.75 \pm 0.10$  for the remainder of the monitoring program (Figure 5-18).

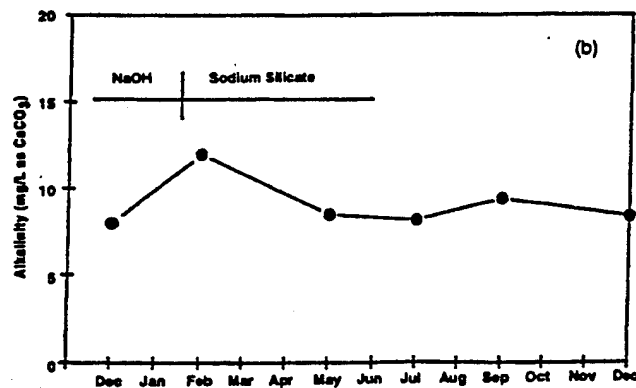
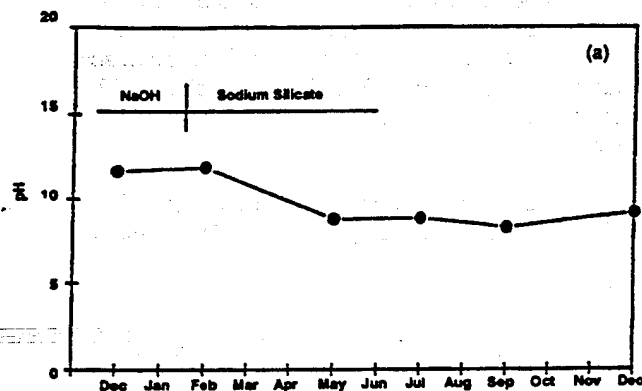


Figure 5-18. Average pH (a) and alkalinity (b) from the distribution sampling events.

At the dead ends of the system, the pH ( $7.52 \pm 0.38$ ;  $n = 3$ ) was lower than the pH ( $8.17 \pm 0.05$ ;  $n = 8$ ) at central points within the distribution system. Lower pH values observed are likely due to the release of metals such as iron, and subsequent hydroxide-ion uptake, which frequently occur in stagnant areas. The lower pH values are generally consistent with lower silica concentrations found in the same regions (see the following discussion on silica).

**Alkalinity.** The alkalinity typically ranged from approximately 5 mg/L as  $\text{CaCO}_3$  at dead-end locations to 10 mg/L at most other points within the system. The average alkalinity remained relatively constant throughout the monitoring period, with the exception of a slight rise during February when the startup dosage of silica was being administered (Figure 5-18b). The increase in alkalinity was probably due to the presence of the anionic silica species,  $\text{H}_2\text{SiO}_4$ .

**Silica.** From the distribution system monitoring data, it can be seen that the silica concentrations in the center of the system were higher ( $17.8 \pm 0.53$  mg/L as  $\text{SiO}_2$ ) than at the ends of the system ( $16.0 \pm 1.2$  mg/L) (Figure 5-19a). These data suggest that silica was being adsorbed onto pipe surfaces as the water moved through the system. Silica has the ability to adsorb onto metal-oxide surfaces (18,19). Potential evidence of this type of

adsorption was observed in this study as the average silica concentration was lower ( $15.6 \pm 1.5$  mg/L;  $n = 3$ ) at sampling sites located on unlined cast iron mains than at sites located on other types of pipe ( $17.5 \pm 0.71$ ;  $n = 9$ ) (Figure 5-19a).

The calculated means of the first- and second-draw saffiles were compared; they displayed evidence of silica adsorption onto the surfaces of home plumbing systems (Figure 5-19b). Although these data suggest adsorption of silica was occurring, it cannot be confirmed without X-ray diffraction analyses.

**Lead.** Figure 5-20 shows the variation in lead concentration of first-draw samples over the monitoring period. Prior to application of sodium silicate, the lead levels ranged from 6 to 488  $\mu\text{g/L}$  and averaged  $84 \pm 145$   $\mu\text{g/L}$ . Over the period of May through December, when the lead levels were relatively stable, the lead concentrations ranged from 5 to 166  $\mu\text{g/L}$  and averaged  $26 \pm 22$   $\mu\text{g/L}$  (Figure 5-20a). These lead levels are relatively high, considering that 11 of the 12 buildings were constructed before 1981. The other building was constructed in 1990 and, as a result, contained pipes with lead-free solder. Since the first-draw sample volume was 250 mL, it is likely that the major source of lead is from brass fittings.

The average lead concentrations were consistently lower during the time when the sodium silicate was being fed. When

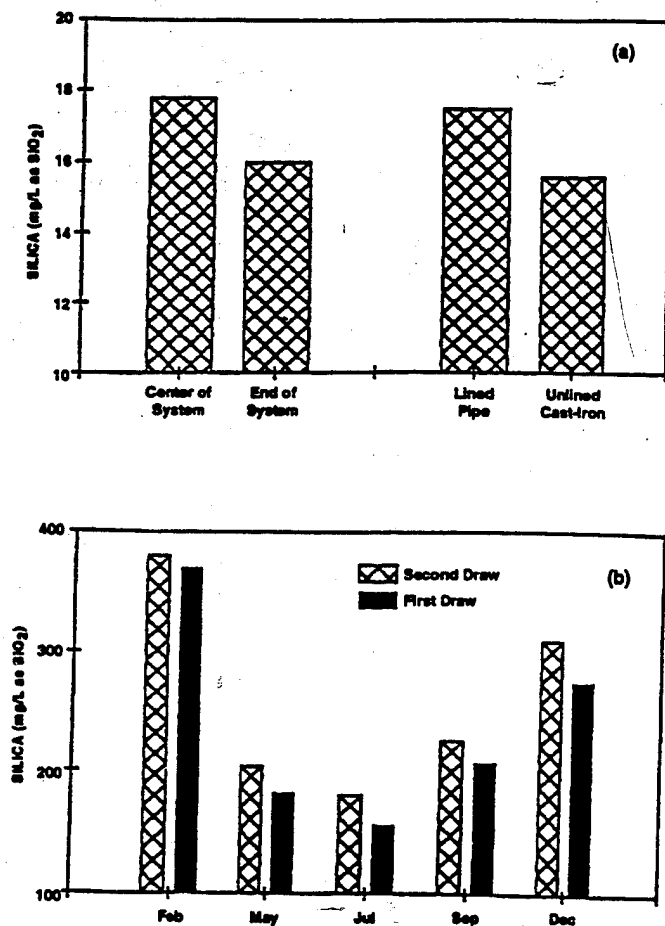


Figure 5-19. Silica concentrations from selected sites within the distribution system (a) and in first- and second-draw samples (b).

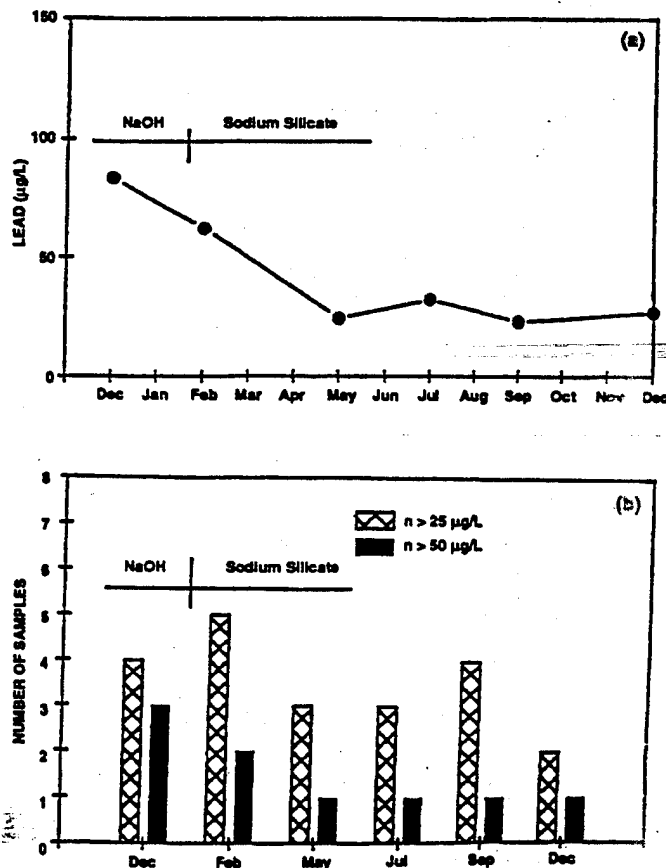


Figure 5-20. Average lead concentrations in the first-draw samples (a) and the number of samples exceeding specified concentrations in first-draw samples (b).

the number of samples exceeding  $>50 \mu\text{g/L}$  as lead and  $>25 \mu\text{g/L}$  as lead (Figure 5-20b) were compared before and after treatment, however, only a slight improvement was observed with the addition of sodium silicate. Second-draw samples, collected after flushing for a minimum of 3 minutes, were typically below the detection limit.

The highest lead concentrations were consistently found in samples collected at monitoring points on dead-end unlined cast iron mains, probably because of the lower pH values witnessed at these locations. Typically, the pH at these locations ranged from 6.6 to 7.2 compared to other sampling locations, where the pH was 7.6 to 8.5.

In general, some sites showed a consistent reduction in lead concentration; at other sites, the concentrations either remained relatively constant or increased. This result is to be expected since the source of lead (e.g., dezincification of brass, or dissolution of lead-tin solder) and types of films present will vary significantly depending on the specific location of the site. In particular, the dezincification of brass fittings, which was probably the major source of lead at most of the sites, can respond erratically to silicate treatment (20).

**Iron.** As shown in Figure 5-21, the iron concentration over time, after silicate addition, gradually decreased, and then increased, probably in response to low flow rates during the following fall and winter months. Each point on the figure represents the average iron concentration of 12 first-draw and 12 second-draw samples.

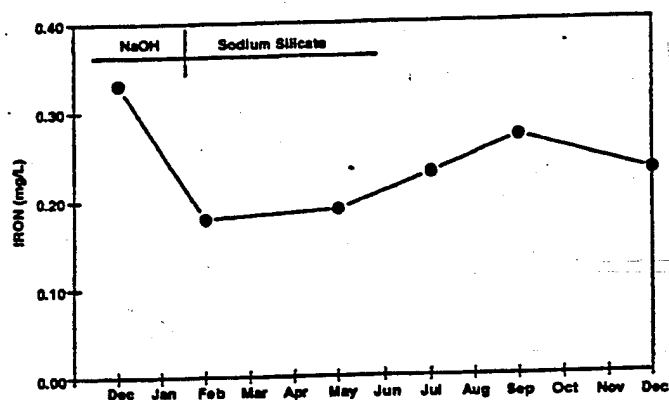


Figure 5-21. Average iron concentrations in the first- and second-draw samples.

During the last 6 months of 1990, the York Water District received approximately 15 red water complaints. Silicate treatment eliminated these complaints over the 12-month trial application. Iron concentrations ranged from  $<0.10$  to  $1.87 \text{ mg/L}$  before treatment, and  $<0.10$  to  $1.37 \text{ mg/L}$  after treatment; therefore, it is likely that the particulate iron was being sequestered by dissolved silica. The ability of sodium silicate to sequester oxidized forms of iron in soft, low-alkalinity water has been well documented (16).

**Copper.** Average first-draw copper concentrations from the six sampling events were especially low (Figure 5-22), as has

been observed in other corrosion monitoring programs under similar water quality conditions (21). A possible reason for the low copper levels is that the first-draw sample volume was 250 mL; as a result, a large portion of the sample volume was contained within brass fittings and was not in contact with copper pipe.

The copper levels decreased during the initial sampling events but later increased during the winter (Figure 5-22). The increase was primarily due to a drop in pH at two monitoring stations located on dead ends. At dead-end monitoring stations located on unlined iron pipe, the copper concentration averaged  $0.39 \pm 0.04 \text{ mg/L}$ , and at all other locations averaged  $0.05 \pm 0.02 \text{ mg/L}$ . When the average copper concentrations are determined excluding dead-end monitoring points, there appears to be a slight reduction in copper levels from the application of silicate over time (Figure 5-22).

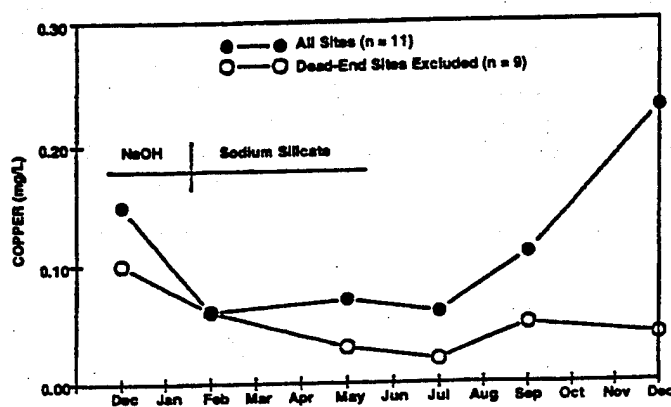


Figure 5-22. Average copper concentrations in the first-draw samples.

### 5.3.5.3 Treatment Costs

Given the average maintenance silica dosage of  $11 \text{ mg/L}$  administered between April and December, the cost of sodium silicate is  $\$8.12$  per million liters. This figure is based on bulk deliveries ( $\geq 15,142 \text{ L}$ ) of Type N<sup>®</sup> liquid sodium silicate and a bulk chemical cost of  $\$21.30/100 \text{ kg}$  ( $\$73.70/100 \text{ kg as SiO}_2$ ).